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CONDUCTED BY

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Journal of Anatomy and Physiology.

NOTES ON THE CRANIOMETRY OF SOME OF THE OUTCASTE TRIBES OF THE PANJAB. By R. HAVELOCK CHARLES, M.D., M.Ch., F.R.C.S.I., F.Z.S., *Surgeon Bengal Medical Service, Professor of Anatomy and Comparative Anatomy, Medical College, Lahore; Surgeon, Mayo Hospital, Lahore; Fellow of the Panjab University.*

It is evident that there is ample field for research in the determination of the race differences of the people in a country such as the Panjab, which has been overrun by wave after wave of invasion—by the Aryan and Scythian hordes, the armies of Alexander, the throngs of Musalmán intruders (successively under Kultugh, Taimur, Nadir and Ahmad Shah), and the multitudes that came under Babar and Humáyún—each acting and reacting upon the others. There has thus been brought about such a diversity in the inhabitants of the province, as imagination can conjecture, would be caused by so many convulsive throbs of conquest and devastation.

The following tables are drawn from the measurement of fifty skulls which I collected in the Comparative Anatomy Museum of this College. With reference to the castes to which their owners in life belonged—Chúhra and Chamár—I have made some remarks, for which I am in a great measure indebted to that most valuable and interesting work by Mr Denzil Ibbetson, C.S., *The Panjab Census Report*, 1881. This, although an Official Report, reads like a novel, and is filled with matter of great ethnological importance. The skulls I measured were taken mostly from patients who, having died in the Mayo Hospital, Central Jail, or Lunatic Asylum, Lahore, were received for dissection in the Anatomical Department of the Medical College.

The sex is authentic, and the ages are approximately correct. They are grouped into castes, Musalmán and Hindoo; but these divisions are, as far as the skulls in question are concerned, religious, and not tribal. Craniometry has got of course to do with the former and not the latter. I have therefore subdivided these divisions again into Chamár and Chúhra, and Musalmán. The skulls are, in my opinion, from individuals of aboriginal as distinguished from Aryan progeny, with the exception of certain megacephalic examples (Nos. 4, 13, 23, 24, 25, 26, 28, 33, 35) amongst the thirty-six Mahomedan male types. It is possible that these may have derived their descent from the more recent Musalmán invaders, coming by way of the north-west frontier, and would therefore be distinct from the Aryan possessors on the one hand and the aboriginal dispossessed on the other.

I may say that, saving some Musalmán bodies, all those received in the dissecting-room are the corpses of Chamárs or Chúhras, whether these, when enjoying the vital breezes, called themselves Sikh, Hindoo, or Musalmán. That is, they come from the outcaste tribes who are considered to be almost certainly aboriginal, though there is little doubt that the aboriginal nucleus has received additions, from other sources, of those who have gradually sunk in the scale of occupation, or have in any way been degraded to the lowest level. Mr Ibbetson says, regarding these outcaste tribes: "A more accurate knowledge of their practices could hardly fail to be of the greatest possible assistance in the attempt to separate the aboriginal from the Aryan element in the current form of Hinduism, and to supply us with a most valuable standard by which to detect aboriginal survivals in the customs of tribes which now claim Aryan descent." I am hopeful that the points brought out in the tables regarding the craniometry may prove useful in the resolution of the ethnic position of the tribes in question. The determination of this, by the study of the customs alone of these tribes, is beset with many difficulties, not only from the extreme intricacy of these, for, as Mr Ibbetson says, "to their own peculiar customs many of them have now added others, not only taken from different religions, but often varying from place to place and even from village to village in the same district, according to the religion of the villagers whom they serve." The connec-

tion between these castes that form the village menials (Chamár and Chúhra, and the agricultural communities whom they serve was, in old times, hereditary and not voluntary—a condition comparable to that of the Canaanite bondsmen to the Israelite conquerors, who turned them into hewers of wood and drawers of water. The result of this continual selection and appropriation from the beliefs and customs of their masters, is an extraordinary medley of religious and semi-religious observances. “Those who have become Sikhs or Musalmáns usually observe the precepts of their new faith with considerable strictness, and, though this does not always avail them against the extension to religious matters of the social exclusiveness which is so abnormally strong in India, yet the Mahomedans generally, and the Sikhs in some respects, are less particular in the matter than the Hindoos themselves.”

Chamárs, or workers in leather, are looked on as unclean by Hindoos, because they use as food the flesh of the Sacred Cow, and they devour also the bodies of animals that have passed away from natural causes. They work in leather, which is an unclean pursuit. The Sikhs, who reverence the cow even more than the Hindoos, detest them also for the same reasons, but the Mahomedans admit Mochis, who are only Musalmán Chamárs, to common devotions. Those Chamárs who have not been thus converted are practically Hindoos. They have no special god, but worship the ordinary deities, especially the minor ones, and offer at the ordinary Hindoo shrines. The Bráhmans who act the part of priests to them get the name of Chamarwa. They wear the sacred thread; but true Brahmáns consider them polluted, and regard them as unclean. The Chamarwa will not, however, eat with their clients, but they preside at their marriage festivities, at which they carry out the Hindoo ritual. The Chamárs dispose of their dead in divers ways. In Ragputana burial is the custom. In the Panjab they generally cremate. “In Sirsa and Hissar they follow either custom indifferently, even in the same family. But whether buried or burnt, the *phúl* (if cremated, the ashes and usual small bones; if buried, the nails of the fingers and toes) are taken to the Ganges for final disposal.” The Chamárs do not believe in transmigration. The course is direct—the good to heaven, the

bad to hell. There is a pathos in the lament of their funeral processions—"then the men with a loud voice mourn and say, "*Tu hi hai! Tainne paida kia, aur Tainne Mária*" (There is but Thou! Thou hast given, and Thou hast taken away). Some Chamárs, having abandoned leather working and become weavers, have been admitted to communion by the regular Sikhs, whose habits and observances they follow with exactitude. The Chúhras (scavengers) are regarded by Sikh, Hindu, and Musalmán alike as utterly polluted, because they remove night-soil and eat carrion and vermin and the leavings of other people. Mr Ibbetson considers that the religion of the Chúhras (of those not converted from the faith of their fathers) as to doctrine bears a resemblance to Christianity—a closer one than that of any other in India. "They worship one supreme being, without form or habitation, and believe that the good go to heaven as soon as they die, while the bad pass into punishment, but for a while only." They always bury their dead. The corpse is placed with mouth downwards, so that the ghost may not escape and walk the earth, the ghost of a sweeper being regarded by the peasantry generally as the most evil-working and harmful of spirits. "Their customs as to marriage apparently often vary with the religion of the villagers whom they serve rather than with their own, Hindu Chamárs following the Mahomedan rites in a Mahomedan village, and *vice versa*, a Mahomedan Chúhra in the one case, and a Chúhra Bráhmaṇ on the other, being called to officiate. The Sikh Chúhras are known as Mazbi, and are said to be followers of the Chúhra, who brought away the pieces of the corpse of Guru Teg Bahadur after he had been executed at Delhi. They take the *páhul*, abstain from tobacco, wear long hair, and are fairly strict Sikhs so far as observances go. But they are kept at a distance by the regular Sikhs. Some of them have abandoned scavenging and taken to leather work, and are known as Rangretas, and considered as of a higher order than the ordinary Mazbi."¹ The Musalmán Chúhras are divided into two classes: first, those who, refusing to remove night-soil, having abandoned their hereditary occupation as to its unsavoury branches, restrict themselves to pure food, and observe

¹ From the Mazbis are now drawn recruits for the Panjab Pioneer regiments.

the ordinances of their faith. Secondly, those who have made no such change. The former are generally admitted to the rites of their religion by the other Musalmáns, the latter are generally excluded, but may be admitted to terms of equality even by Mahomedan Rajputs, while in some places not only the latter but also the former are looked on as irrevocably unclean. There is much diversity of practice, and the line is difficult to draw."

Though caste is generally thought immutable, it is by no means in reality so. This is to be borne in mind when directing one's attention to the megacephalic skulls already mentioned. It is possible even in India, as in Europe, for individuals to rise or fall in caste. For instance, one Chamár takes to weaving, dropping leather work. He becomes a Chámar-Juláha; presently he will be a Juláha pure and simple; another does the same, and becomes a Rangreta or a Búnia. A Chúhra refuses to touch night-soil, and becomes a Musalli or a Kutána. The same process occurs amongst the higher Hindu castes. Amongst Musalmáns the like happens, as the sarcasm of the proverb—"Last year I was a Sweeper, this year I am a Shekh, next year, if prices rise, I shall be a Saiyad"—shows the process that is going on daily. As there is a progress of evolution of the lower to the higher, there is also a process of degradation from the higher to the lower. I am inclined to think that the microcephalic skulls are probably aboriginal, and the megacephalic are not so. For purposes of comparison I have grouped together tables of measurements of English, Chinese, Negro, Australian, Andaman Islander, and Mongolian skulls (taken from 9th ed. Quain's *Anatomy*, vol. i.) with those measurements of the crania that I have examined. These latter I have subdivided into forty-one skulls partaking of characters in common, and nine skulls quite different in type, and bearing a close resemblance as to cranial capacity, &c., to those of European nationality.

The methods of measurement and classification which I have employed are those which were used by Professor Flower, C.B., in the preparation of his *Catalogue of the Crania in the Museum of the Royal College of Surgeons of England*,¹ and which are fully explained in that well-known work.

¹ London, 1879.

In the tables appended to this paper the upper row of numerals opposite each specimen express the measurements in millimetres; those in the lower row are the equivalents in English inches.

The skulls are numbered 1 to 50, with caste (M = Musalmán, H = Hindoo) following. Sex and age are also denoted. All are adult skulls. All, save those numbered 4, 13, 23, 24, 25, 26, 28, 33, and 35, may be regarded as of typical representatives of the skulls of members of the outcaste tribes (Chamár and Chúhra). Those numbered 4, 13, 23, 24, 25, 26, 28, 33, 35 are the skulls of Panjabi Musalmáns, who, by degradation, have gravitated amongst the outcastes socially, but tribally are not connected with them.

The average Chúhra skull (41 skulls) has a cranial capacity of 1303 c.c., is dolichocephalic (70), orthognathous (83), mesorhine (50), and mesoseme (88).

The average Panjabi Musalmán skull (9 skulls) has a cranial capacity of 1511 c.c., is dolichocephalic (70), orthognathous (90), leptorhine (47), and mesoseme (89).

Certain points of interest are noted as regards—

1. *Condition of Sutures.*—In 64 per cent. Wormian bones were found in the lambdoid, sagittal, frontal, or petro-sphenoid. sutures. In 32 per cent. epipteric bones were present. The number of the Wormian bones in any skull varied from 1 to 14. The size of the bones varied from $\frac{1}{3}$ inch or larger to $1\frac{1}{2}$ inch. Frontal or metopic suture was persistent in 8 per cent. These were the skulls of criminals received from the Central Jail. It will be noted that in not a few instances the lambdoid suture was very complicated, while the coronary and sagittal were simple.

2. *Condition of Glabella.*—In 60 per cent. it was either prominent or very prominent; in 40 per cent. it was flat or depressed.

3. *Condition of Inion.*—In 34 per cent. it was very small, flat, or absent.

4. *Condition of Jugular Foramina.*—In 82 per cent. the right was larger than the left, frequently twice or thrice as large. In 8 per cent. the left was larger than the right; in one instance double the size. In 10 per cent. both foramina were equal in size. Intra-jugular processes were sometimes present, oftener absent; when present, most often found only on one side, and that the left.

5. *Post-Condylloid Foramina.*—In 54 per cent. only were both present in the same skull. In 14 per cent. both were absent. It was noted that the size or presence of the foramina seemed to bear a

relation to the large or small size of the jugular foramina. When the jugular foramen was smaller than usual on one side, the post-condyloid foramina on same side was larger.

6. *Parietal Foramina*.—Absent on both sides in 38 per cent.; present on both sides in 28 per cent.

7. *Size of Pterion—Parieto-sphenoidal Suture*.—In 32 per cent. epipteric bones were present, which in some cases encroached on the length of the parieto-sphenoidal suture; in other cases separated the parietal entirely from the great wing of sphenoid. These points and the measurements of the pterion on both sides are noted.

8. The *Par-Occipital Process* was large or prominent in 66 per cent.

TABLE I.—MEASUREMENTS

The upper row of figures appertaining to each skull gives the measurement and 35, being those of Panjabi Musalmáns; the

M.	M.	44	17"	30 $\frac{1}{2}$ "	9"	11 $\frac{1}{2}$ "	14 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	10 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	1375
2	M.	32	433-6	406-2	212-12	411	368-5	117-2	137-1	114-6	284	307-6	251-6	129-8	126-5	126-5	121-5	M1.
3	M.	32	17 $\frac{1}{2}$ "	19 $\frac{1}{2}$ "	8 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	14 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	12 $\frac{1}{2}$ "	9 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	1340
3	M.	38	425	408-1	229	464-1	381	129-5	134-6	117-2	279	296-7	279	124-2	122-6	124-2	106-7	
4	M.	38	16 $\frac{1}{2}$ "	19 $\frac{1}{2}$ "	8"	10 $\frac{1}{2}$ "	15"	5 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	11"	11 $\frac{1}{2}$ "	11"	4 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	
4	M.	55	444-6	527	141-6	283-3	286	137-1	134-6	114-6	294-2	307-6	269	127	126-6	137	111-6	
5	M.	55	17 $\frac{1}{2}$ "	30 $\frac{1}{2}$ "	9 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	16 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	12 $\frac{1}{2}$ "	10 $\frac{1}{2}$ "	5"	4 $\frac{1}{2}$ "	5"	4 $\frac{1}{2}$ "	1490
5	M.	60	432	513	117-2	139-6	368-6	129-5	129-5	109-6	291-6	299-8	249-3	121	127	137	106-7	M1.
6	M.	35	17 $\frac{1}{2}$ "	30 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	14 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	9 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	5"	5"	4 $\frac{1}{2}$ "	1300
6	M.	35	444-6	508-3	224	269-2	368-6	127	127	109-6	291-6	299-8	254	128-6	126-6	130-1	109-9	M1.
	M.	35	17 $\frac{1}{2}$ "	19 $\frac{1}{2}$ "	9 $\frac{1}{2}$ "	10 $\frac{1}{2}$ "	14 $\frac{1}{2}$ "	5"	5"	4 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	10"	5 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	1300

OF FIFTY ADULT SKULLS.

in millimetres; the lower row in inches (Nos. 4, 13, 23, 24, 25, 26, 28, 33, remainder of members of outcast tribes proper).

[illegible]

|

7A"	6A"	5A"	70	103	51-5	88	68-8	ridges well marked.	Complicated, also Par.-Mastoid.
179-6	122-6	147-6	---	---	---	---	---	Full.	Coronary complicated; Sag. and Lambdoid partly obliterated.
7A"	4A"	3A"	69	96-8	43	84	75-4	Depressed.	Flat.
189-6	124-2	130-1	---	---	---	---	---	Full.	Lambdoid complicated; large w. (1" x 1/2") in Lambdoid; Sag. and Lambdoid partly obliterated.
7A"	4A"	5A"	65	94	49-4	84-4	68-8	Flat.	Very prominent.
189-6	131-7	133-8	---	---	---	---	---	High and ridged Sag. Crest; roof-like.	Sag. obliterated, also part Coronary and Lambdoid.
7A"	5A"	5A"	69	88-4	47	84	70	Very prominent.	Very prominent.
181-1	131	130-1	---	---	---	---	---	Full.	Lambdoid complicated and part obliterated; Sag. obliterated, and Coronary partly so below.
7A"	4A"	5A"	69-9	100	53	83	71-9	Very prominent.	Small.
181-7	129-1	131-7	---	---	---	---	---	Full and wide.	Sag. complex behind, but less so than Lamb.; Occ. Mast. very complex; Arborescent Cor. complex at sides.
7A"	4A"	5A"	71-3	98-4	41	81-6	73-1	Very prominent.	Very small.
181-8	137	139-6	---	---	---	---	---	Full and wide.	Cor. and Lamb. obliterated, save lower extremities L., which are complex.
7A"	5"	5A"	68-9	100	55-1	83-6	75-8	Depressed.	Flat.
179-6	122-6	147-6	---	---	---	---	---	Full.	Coronary complicated; Sag. and Lambdoid partly obliterated.
7A"	4A"	3A"	69	96-8	43	84	75-4	Depressed.	Flat.
189-6	124-2	130-1	---	---	---	---	---	Full.	Lambdoid complicated; large w. (1" x 1/2") in Lambdoid; Sag. and Lambdoid partly obliterated.
7A"	4A"	5A"	65	94	49-4	84-4	68-8	Flat.	Very prominent.
189-6	131-7	133-8	---	---	---	---	---	High and ridged Sag. Crest; roof-like.	Sag. obliterated, also part Coronary and Lambdoid.
7A"	5A"	5A"	69	88-4	47	84	70	Very prominent.	Very prominent.
181-1	131	130-1	---	---	---	---	---	Full.	Lambdoid complicated and part obliterated; Sag. obliterated, and Coronary partly so below.
7A"	4A"	5A"	69-9	100	53	83	71-9	Very prominent.	Small.
181-7	129-1	131-7	---	---	---	---	---	Full and wide.	Sag. complex behind, but less so than Lamb.; Occ. Mast. very complex; Arborescent Cor. complex at sides.
7A"	4A"	5A"	71-3	98-4	41	81-6	73-1	Very prominent.	Very small.
181-8	137	139-6	---	---	---	---	---	Full and wide.	Cor. and Lamb. obliterated, save lower extremities L., which are complex.
7A"	5"	5A"	68-9	100	55-1	83-6	75-8	Depressed.	Flat.

M.	M.	40	19"	31½"	39"	11½	15½'	4½"	5½"	5½"	11½"	13½"	11"	5½"	5½"	5½"	4½"
21			432	508	244-8	263-5	381	120-6	127	114-6	298	291-6	260-3	117-6	117-6	114-6	105-1
M.	M.	36	17"	20"	9½"	10½"	18"	5½"	5"	4½"	11½"	11½"	10½"	4½"	4½"	4½"	4½"
22			454-2	514-3	225-3	379	575	126-5	127	111-5	288-5	301-2	261-2	127	120-1	121-7	111-6
M.	M.	40	17½"	20½"	9½"	11'	14½"	5½"	5"	4½"	11½"	11½"	9½"	5"	5½"	5½"	4½"
23			457	539-3	241-6	298	390-5	126-5	117-6	126-5	288-5	305	263-5	128-5	127	127	116-2
M.	M.	38	15"	21½"	9½"	11½"	15½	5½"	4½"	5½"	11½"	12"	10½"	5½"	5"	5"	4½"
24			466-5	542-5	232-5	305	400	123-5	126-6	127	294-6	320	263-5	123-3	124-9	124-9	111-5
M.	M.	50	18½"	21½"	9½"	12"	15½"	5½"	5½"	5"	11½"	12"	10½"	5½"	5½"	5½"	4½"
25			487	533	244-8	288-5	392-6	123-3	123-3	127	294-6	305	266-5	121-7	123-3	123-3	114-6
M.	M.	26	18"	21"	9½"	11½"	15½"	5½"	5½"	5"	11½"	12"	10½"	5½"	5½"	5½"	4½"

128-4	128-5	128-1	...	...	...	...	...	Full; temp.- ridges promin- ent.	Cor. simple; Sag. and Lamb. complex.	Prominent.	Small.	R. much l Int. Jug. P root.	
7 1/4"	5 1/4"	5 1/4"	67-5 D.	92-4 O.	50 M.	92 Mg.	72-5						
										Flat.	Prominent.		
											R. larger, 1 1/2", 12-6; no Int. Jug. P.; R. Carotid Canal smaller; L. 1/4", 7-9; Int. Jug. P. present.	R. present; L. absent.	Very large.
											Absent.	Large.	
											R. is a squamo- frontal suture. L. 1/4", 6-8.	R. 1/4", 8-10. epipteric b imposed, 1/4", Par. Sph. an	Large.
Small; R. Jugular Proc., perf. by foramen, opening into Lat. Sinus.													

continued.

TABLE I.—

H.	M.	50	17½"	10½	8½"	11"	14½"	5½"	5½"	4½"	11"	12"	9½"	4½"	4½"	4½"	4½"	1190
41			435.1	511.1	341.6	369.8	375	133.8	134.2	117.6	283.1	294.6	244.6	134.2	125.6	125.6	125.6	MI.
H.	F.	45	17½"	20½	9½"	10½"	14½"	5½"	4½"	4½"	11½"	11½"	9½"	4½"	4½"	4½"	4½"	1290
42			419.6	472.8	212.6	290.3	345.6	111.6	124.2	111.6	290.3	291.6	235.6	117.6	121	121	106.1	MI.
M.	F.	28	16½"	18½"	8½"	10½"	13½"	4½"	4½"	4½"	10½"	11½"	9½"	4½"	4½"	4½"	4½"	1010
43			441.6	489.3	233	273	362.3	127	130.1	106.1	273	306	260.3	125.6	125.6	127	109.9	MI.
M.	F.	35	17½"	19½"	8½"	10½"	14½"	5½"	4½"	4½"	11"	12"	10½"	4½"	4½"	5"	4½"	1330

continued

continued.

TABLE II.—Comparative Table of Skulls of Nine Different Nationalities.

	Average Cranial Capacity in cb. cē	INDICES					
		Cephalic.	Altitudinal	Gnathic.	Nasal	Orbital.	
ENGLISH,	1511	76	71	96	46	88	The low Cranial Capacity (1808) of the Skulls of the true Chūhra and Chamār, as compared with the comparatively high capacity (1511) of the Skulls of the Panjabi Musalmāns, and the close resemblances of the measurements of the Skulls of these latter with those given in the Table as English Skulls will be observed.
CHINESE,	1424	79	75	99	50	90	
AFRICAN NEGROES,	1388	...	...	...	...	...
ANDAMAN ISLANDERS,	1244	82	77	...	...	91
FITI ISLANDERS, . . . . .	...	66	74	103	...	...
NATIVE AUSTRALIANS,	1296	71	71	104	57	81	
50 Skulls—Chamār and Chūhra Castes, Panjab,	1340	70	71	97	49	88	
41 Skulls—(deducting from 50 the 9 Megacephalic Skulls probably not of same tribes),	1303	70	72	83	50	88	
9 Skulls—Megacephalic (of Panjabi Musalmāns included in the 50, but probably not of the Chamār tribe),	1511	70	70	90	47	89	

TABLE III.—*Analysis of Fifty Skulls.*

Number of Skulls— 35 Male Musahman, 9 Female " 4 Male Hindu, 1 Female "	Average Cranial Capacity in cu. ct. (1840).	AVERAGE INDICES.					Average Diameters in Millimetres and Inches.		
		Cephalic (70-6).	Altitudinal (71).	Gonathic (91-6).	Nasal (48-6).	Orbital (88-9).	Long.	Altitu- dinal.	Trans.
30 Skulls. Male Musahman.	1375 = Mesencephalic. (Meg. = 9 Skulls, Me. = 12 " MI. = 15 ")	70 = Dolichocephalic. (Do. = 36 Skulls, Me. = 0 " Br. = 0 ")	= 72	92 Orthognathous. (O. = 31 Skulls, M. = 6 " P. = 0 ")	49-6 Mesorhina. (M. = 21 Skulls, P. = 6 " L. = 10 ")	88-9 Mesence. (Meg. = 16 Skulls, Me. = 11 " MI. = 9 ")	183 7" 3	123 4" 9	139-9 5" 1
9 Skulls. Female Musahman.	1328 = Microcephalic. (Meg. = 0 Skulls, Me. = 1 " MI. = 8 ")	71-7 = Dolicho- cephalic. (Do. = 9 Skulls, Me. = 0 " Br. = 0 ")	= 72	94 Orthognathous. (O. = 7 Skulls, M. = 3 " P. = 0 ")	51-4 Mesorhina. (M. = 4 Skulls, P. = 3 " L. = 9 ")	89-8 Mesence. (Meg. = 4 Skulls, Me. = 3 " MI. = 2 ")			
4 Skulls. Male Hindu.	1398 = Microcephalic. (Meg. = 0 Skulls, Me. = 3 " MI. = 3 ")	70 = Dolichocephalic. (Do. = 4 Skulls, Me. = 0 " Br. = 0 ")	= 71-4	88 Orthognathous. (O. = 4 Skulls, M. = 0 " P. = 0 ")	47-6 Leptorhina. (M. = 1 Skulls, P. = 1 " L. = 2 ")	88-9 Mesence. (Meg. = 3 Skulls, Me. = 1 " MI. = 1 ")			
1 Skull. Female Hindu.	1390 = Microcephalic.	68-6 = Dolicho- cephalic.	= 70-4	90-2 Orthognathous.	83-3 Platyrhina.	84 Mesence.			
Total Average of 40 Skulls.	1340 = Microcephalic.	70-6 = Dolicho- cephalic.	= 71	91-6 = Orthog- nathous.	49-6 = Mesorhina.	88-9 = Mesence.			
Analysis of 50 Skulls.	Meg. = 9 Skulls, Me. = 15 " MI. = 26 ")	Do. = 50 Skulls, Me. = 0 " Br. = 0 ")		O. = 43 Skulls, M. = 7 " P. = 0 ")	M. = 26 Skulls, P. = 10 " L. = 14 ")	Meg. = 22 Skulls, Me. = 16 " MI. = 12 ")			

It is to be borne in mind that 41 of these skulls, although taken from so-called Hindu or Musahman corpses, are undoubtedly of the Chamdr and Chudra tribes. The two former terms are religious divisions and useless when studying Craniometry. Nine skulls are from individuals who, there is reason to believe, by descent bear no relation to the tribes in question. These points are entered into and explained more fully in the brief introduction.

THE AIR-BLADDER AND EAR OF BRITISH CLUPEOID FISHES. By W. G. RIDEWOOD, B.Sc., F.Z.S.

NOTWITHSTANDING the lengthy descriptions of the air-bladder and the ear of Clupeoid fishes given by Weber, Breschet, Hasse, Retzius and others, our information on this subject is singularly fragmentary, and no apology is therefore necessary in presenting a short and connected account of the comparative anatomy of these organs in the six species of Clupeoid fishes found around the British coast, viz., the five British species of *Clupea*,—the Herring (*C. harengus*, L.), the Pilchard (*C. pilchardus*, Walb.), the Sprat (*C. sprattus*, L.), the Allis Shad (*C. alosa*, L.), the Thwaite (*C. finta*, Cuv.), and the Anchovy (*Engraulis encrasicolus*, Cuv.),—which has been shown by Cunningham,¹ Wemyss Fulton,² and others, to be a constant inhabitant of the British seas, although in numbers so variable and quality so poor that its capture does not form a recognised branch of British fishing industry.

A very complete and accurate account of the air-bladder and ear of the Herring was written by Weber³ in 1820, accompanied by most excellent figures, and it is from this source that the text-book descriptions are, apparently without exception, derived.

Breschet,⁴ in 1838, gave a detailed and illustrated account of the ear of *Clupea alosa*,⁵ and a cursory description with an indifferent figure of the air-bladder. As will be seen in the sequel, several of his determinations must be rejected.

Hasse⁶ also, in 1873, published an illustrated account of the swim-bladder and ear of the Herring in his paper on the swim-bladder of fishes.

A very detailed description of the membranous labyrinth of the ear of the Herring, illustrated by three greatly enlarged figures, was furnished by Retzius⁷ in 1881, in his monograph on the ear of Vertebrata, while several good figures of the skull of the Herring, with

¹ *Jour. Marine Biol. Assoc.*, vol. i. No. 3, p. 328 *et seq.*

² *Rept. Fish. Bd. Scot.*, 1890, p. 351.

³ *De Aure et Auditu Hominis et Animalium*, Lipsiæ, 1820.

⁴ *Recherches sur l'organe de l'ouïe des Poissons*, Paris, 1838.

⁵ See p. 30.

⁶ *Anatomische Studien*, pp. 588–610.

⁷ *Das Gehörorgan der Wirbelthiere*, Stockholm, 1881, vol. i. p. 82, and taf. xiv.

detailed descriptions, have been published by Duncan Matthews,¹ which serve to show the relations which the anterior vesicles of the air-bladder bear to the cranial bones.

Beyond the above papers our information on this subject is of the most scanty description, consisting chiefly of passing allusions to these organs in the Clupeoids, in accounts of the osteology, sense-organs, and viscera of Teleostean fishes generally.

The Air-bladder or Swim-bladder.

The body of the air-bladder in the six Clupeoid fishes examined is elongated, and extends the whole length of the post-pericardiac cœlom; its walls are smooth, thin, and of a silvery white colour. This silvery hue is most brilliant in the Herring and Sprat, it is somewhat duller in the Pilchard, while in the Thwaite and Allis Shads, and in the Anchovy, the lustre is very considerably less; the silvery colour is, moreover, limited to the body of the air-bladder, and is not continued on to the two canals into which it branches anteriorly, nor to the ductus pneumaticus, and in the Sprat only, of the forms examined, is it continued to the extreme posterior end of the air-bladder in the region of the anus. As might be expected, the silvery lustre diminishes on inflating the air-bladder.

The middle portion of the air-bladder is apparently much more distensible than the ends. This is especially noticeable at the anterior end, which has the form of a cylindrical tube of less diameter than the middle portion of the air-bladder, the transition being often abrupt and conspicuous. The length of this anterior non-distensible portion is not constant even in the same species, but the limits within which the variation takes place are fairly constant.

In the species of *Clupea* examined this anterior tubular portion, about one-eighth or one-tenth of the length of the cœlom, differs from the more distensible part of the air-bladder only in diameter, the general appearance and histological structure being the same in the two; but in the Anchovy the portion below the 3rd to the 7th vertebræ is very narrow, firm, and somewhat rigid, the lumen is extremely small, and the general characters resemble very closely those of the two air-ducts into which this tube branches anteriorly. The transition from this to the

¹ *Rept. Fish. Bd. Scot.*, 1884, Appendix, p. 55.

succeeding portion of the air-bladder is very sudden. It is preferable, however, to regard this tube in the Anchovy as an elongation of the median cartilaginous structure formed by the confluence posteriorly of the paired air-ducts rather than as a modification of the anterior tubular non-distensible portion of the coelomic air-bladder with which its position would render it comparable.

The coelomic portion of the air-bladder lies on the dorsal side of the body cavity in the median line, between the kidneys; the middle and posterior parts lie slightly below, but the anterior fifth or sixth rather above the level of the kidneys.

The Ductus Pneumaticus.

The coelomic portion of the air-bladder is in communication with the posterior tapering end of the cardiac portion of the stomach¹ by the *ductus pneumaticus*, which opens into the air-bladder by a longitudinally oval aperture, situated in the ventral median line at about the middle, or somewhat behind the middle, of its length, opening slightly more anteriorly in the young than in the adult.

The ductus pneumaticus passes up between the two generative glands and behind the spermatic or ovarian arteries.

If traced from the stomach to the bladder, it is seen to become gradually thinner, and runs first backwards, then forwards, and finally for a very short distance upwards. Very frequently it is convoluted in a more or less spiral manner. The ductus pneumaticus is an open communication between the stomach and air-bladder; it usually contains a quantity of mucus, but, by taking due precautions and thoroughly irrigating the interior of the stomach, coloured injection media can be passed without fail from the one to the other.

The ductus pneumaticus is relatively longer in the adult Herring than in the young; it is relatively shorter and broader in the Sprat and the Thwaite Shad than in the Herring. In the Thwaite Shad it is $\frac{1}{16}$ inch in diameter in its narrowest part.

¹ Professor Huxley (*Nature*, April 28, 1881, p. 608) regards this cæcal portion of the gut as a *Crop*; Breschet (*loc. cit.*) speaks of it as the *Œsophagus*; while Cleland (*Memoirs and Memoranda in Anatomy*, London and Glasgow, 1889, vol. i. p. 171) throws out a suggestion that this so-called stomach of the Herring is really a backward prolongation of the *Pharynx*.

The Posterior Opening.

The air-bladder of the Herring was shown by Weber,¹ in 1820, to open directly on to the exterior by a small aperture lying to the left side of the "ostium genitale." This interesting fact was, however, apparently lost sight of, being only mentioned once² in subsequent publications, until in 1880 it was rediscovered by Bennett.³

Couch,⁴ writing in 1865, may have been aware of the presence of this posterior opening of the air-bladder, but he certainly does not make the fact clear in his context. On page 107 he says, in a short description of the air-bladder of the Herring: "Posteriorly it reaches close to the vent." No one would infer from this sentence that the air-bladder opened posteriorly on to the exterior; but yet a reference to such an opening might possibly be implied in his description of the Allis Shad on page 117: "The air-bladder is long and slender, and the tube which connects it with the vent is even more slight than in the Herring."

This direct communication between the air-bladder and the exterior is present in the Herring, Pilchard, Sprat,⁵ Allis Shad, and the Anchovy; and in these the relations of the posterior end of the air-bladder to the surrounding parts are fairly constant.

There is a shallow longitudinal depression, in fact, a sort of cloaca, into which the three ducts—the anal, genital, and urinary—open; for even in the male, where the genital duct opens on the same papilla as the ureter, there are two distinct apertures, separated by a slight ridge or fold. The urinary papilla, or the urinogenital papilla, according to the sex, stands out in the middle of this cloaca, and projects very slightly on the ventral surface of the animal.

¹ *Loc. cit.*, p. 73.

² By Rathke, in 1824, *Neueste Schriften der Naturf. Gesellschaft in Danzig*, Bd. i. Heft 3, p. 94.

³ *Jour. Anat. and Phys.*, 1880, p. 405.

⁴ *History of Fishes of British Islands*, vol. iv.

⁵ F. Day (*British Fishes*, 1880–84, plate cxxxix. fig. 2a) figures the air-bladder of the Sprat as tapering posteriorly to a point; but in the *Zoologist*, 1882, p. 24, he admits this error by describing "a posterior opening into the progenital canal" in both the Pilchard and Sprat, as in the Herring.

The posterior end of the air-bladder, except in the Sprat, is destitute of the silvery pigment so characteristic of the main body of the air-bladder, and it does not lie freely in the coelomic cavity, but is buried up between the most posterior portions of the genital and urinary ducts and the body-wall of the left side. This portion of the air-bladder is $\frac{1}{4}$ to $\frac{1}{2}$ inch in length, and opens on the left side of the cloacal depression, usually by the side of the genital duct, being thus posterior to the anus, but anterior to the urinary aperture.

The exact position may vary slightly in different specimens. Bennett¹ describes some exceptional arrangements of the four openings into the cloaca in the Herring.

In the Sprat the posterior end of the air-bladder is silvery, even up to its external aperture, and its course is therefore more easily traced than in the other forms.

In the Thwaite Shad a different state of things obtains, for the air-bladder tapers posteriorly to a point, and does not open on to the exterior. This posterior termination is situated antero-ventrally to the vesicle formed by the confluence of the posterior ends of the two ureters, and there is no indication of a flexure to the left as in other species; the pointed extremity, moreover, does not differ in colour or texture from the main abdominal portion of the air-bladder, and it is but loosely held in the connective tissue surrounding the posterior portions of the rectum and the genital and urinary ducts.

Breschet,² in his description of the air-bladder of the Shad, says—"Son extrémité postérieure se termine en une pointe extrêmement aiguë au dessus du cloaque." This anatomical fact, coupled with the small number and the shortness of the gill-rakers seen in his figure,³ shows conclusively that the specimen here described is what is now known as the Thwaite Shad, for the Shad originally described as *Clupea alosa* by Linnæus was the one with stout gill-rakers, i.e., the Thwaite.⁴

¹ *Loc. cit.*

² *Loc. cit.*, p. 13.

³ Pl. IV. fig. (1).

⁴ For the explanation of the fact that the name *Clupea alosa*, L., is now applied to the Shad with many long gill-rakers, see Günther, *Brit. Mus. Cat. of Fishes*, vol. vii. p. 434.

*The Air-Ducts.*¹

The anterior end of the coelomic air-bladder in the Herring divides just behind the two great wings of the parasphenoid into two very thin tubes, of a consistency described by Breschet and others as cartilaginous, and with an extremely narrow lumen. These run forwards on the right and left sides of the parasphenoidal wings in a slightly upward and outward direction, and are continued forwards through the exoccipital bone. These tubes are the "canaliculi pellucidi" of Weber,² and the "trompes cystiques" of Breschet.³

These ducts are not strictly circular in section, but rather oval, and measure about .12 inch in diameter.

The extreme anterior end of the coelomic air-bladder partakes of the same cartilaginous nature as the ducts, and so the latter may be said to unite with one another behind, and to open backwards into the air-bladder by a single aperture.

This median cartilaginous extremity of the abdominal air-bladder is very short in the species of *Clupea* examined, but, as already mentioned, it is represented in the Anchovy by a delicate tube, about $\frac{1}{2}$ inch in length, and but slightly greater in diameter than the paired air-ducts. The transition between this median air-duct and the air-bladder behind it is very sudden.

The air-ducts are tubular, although the lumen is extremely small, and very finely-divided indigo suspended in water can be passed from the air-bladder to the air-vesicles in the Herring and Pilchard at least.

The late Duncan Matthews also demonstrated the tubular nature of the air-ducts in the Herring a few years ago, by cutting a series of sections along their whole length.

Valenciennes was, therefore, not justified in asserting so positively that these air-ducts are simply *ligaments* attaching the anterior end of the air-bladder to the skull.

In his description of the Herring he states⁴—"Je me suis

¹ This name is only provisional, and is intended to designate the extent of the paired cartilaginous tubes as far forwards as their bifurcation at the triradiate suture between the pro-otic, pterotic and exoccipital.

² *Loc. cit.*, p. 20.

³ *Loc. cit.*, p. 13.

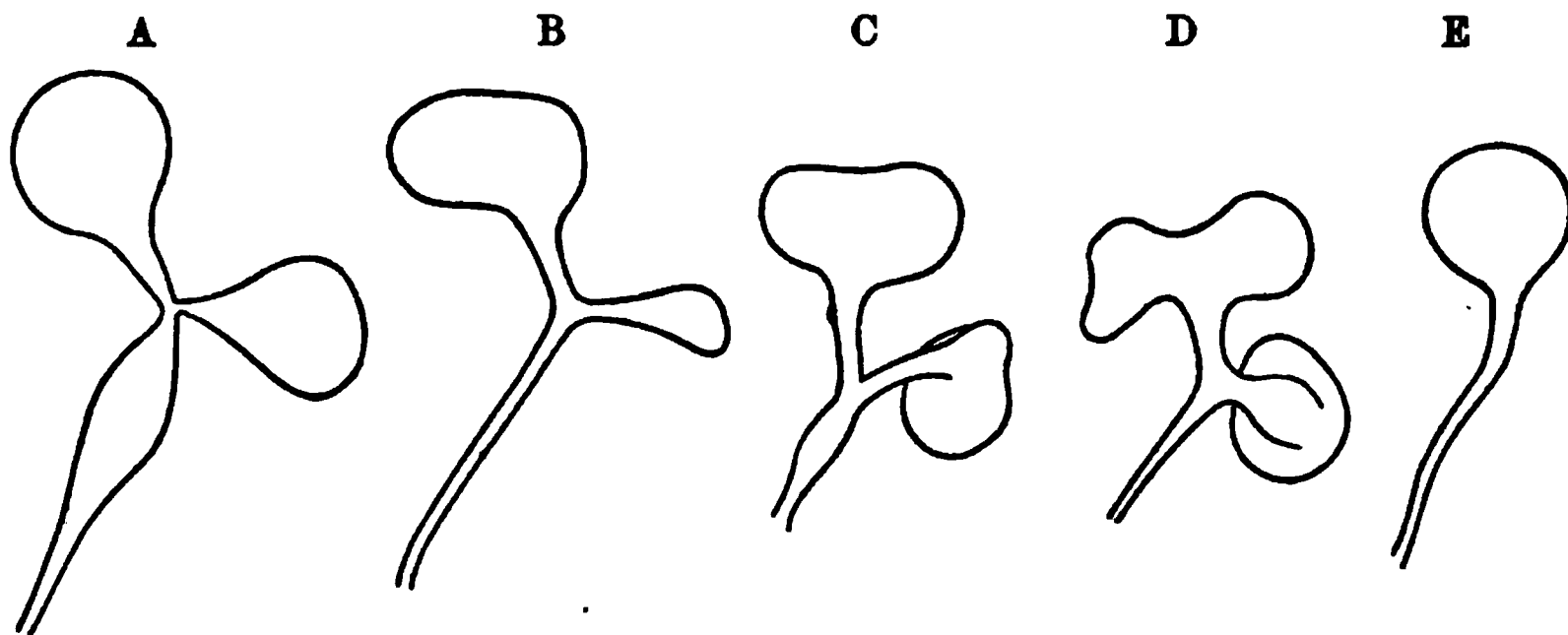
⁴ *Hist. Nat. des Poissons*, vol. xx. p. 40.

assuré par des sections répétées et par l'examen microscopique que cette bride est pleine. . . . J'insiste avec beaucoup de soin sur la nature de cette bride, parce que presque tous les anatomistes se sont trompés sur ce ligament;" and again on the same page—"Il ne peut donc rester de doute à cet égard, ces brides ne sont pas des tubes creux."

The air-duct of each side passes forwards, and slightly outwards and upwards, and after running a short distance in a groove in the exoccipital bone, penetrates the latter at a point situated immediately behind the fenestration between the exoccipital and basioccipital, known as the auditory fenestra. In the Herring, about two-thirds of the duct is thus enclosed in bone.

The bony envelope of both the duct and its vesicles invests these appendages of the air-bladder very closely, and the layer of bone in contact with the latter is denser and harder than the rest, so that it is possible, by carefully breaking away the softer bone, to obtain a bony counterpart of the vesicles and tubes contained within it.

There is, however, no intimate connection between the walls of these appendages of the air-bladder and their bony envelopes, the two being readily separated by breaking off the bone.



Outline figures of the bony envelopes of the air-vesicles and ducts of the left side. Ventro-lateral view:—

A.	<i>Clupea harengus</i> , L.,	.	.	.	.	× 3
B.	„ <i>alosa</i> , L.,	.	.	.	.	× 3½
C.	„ <i>pilchardus</i> , Walb.,	.	.	.	.	× 3½
D.	<i>Engraulis encrasicolus</i> , Cuv.,	.	.	.	.	× 4½
E.	<i>Clupea sprattus</i> , L.,	.	.	.	.	× 3½

The air-duct does not penetrate any bone but the exoccipital;

it bifurcates anteriorly at the suture between the latter and the pro-otic. The bony exoccipital tube, in which its anterior end runs, is continued behind for a short distance as a groove opening downwards and inwards.

In the Herring the air-duct is dilated within the exoccipital to form a fusiform chamber, the greatest diameter of which is approximately in the middle of that portion enclosed in the bone.

In the Pilchard the air-ducts are longer and thinner than those of the Herring; they run forwards horizontally, and then bend somewhat abruptly outwards and upwards, whereas those of the Herring have a more uniform forward, outward, and upward course.

The anterior end, enclosed in bone, is slightly dilated and fusiform in shape, but does not attain to such a size as in the Herring; moreover, this dilatation in the Pilchard is very variable, being hardly recognisable in some specimens.

In the Sprat the air-ducts are relatively longer and thinner than in the Herring, and their course is considerably more vertical; there is no trace of any enlargement corresponding to the fusiform chamber of the Herring.

In the Anchovy, also, there is no dilatation of the air-ducts. They are a quarter of an inch in length, and are extremely thin; they run forward in a horizontal direction, and are parallel, except at the anterior end, where they diverge somewhat as they penetrate the exoccipital.

In the Allis Shad the ducts are nearly straight, but in the Thwaite they are markedly angulate, running first forward and then bending suddenly upwards.

The lumen of these ducts is very narrow, but increases suddenly and abruptly near the anterior end by the thinning of the wall without affecting the external appearance of the duct, so that it is only by injection that this fact can be demonstrated.

This enlargement of the cavity of the duct evidently represents the fusiform chamber of the Herring, but it is important to note that there is no corresponding enlargement of the bony tube.

The Air-Vesicles.

In the Herring, the air-duct of each side divides at the anterior edge of the exoccipital into two tubes, one of which runs forwards in a horizontal direction, and opens into the anterior vesicle, while the other runs outwards and slightly upwards to communicate in a similar manner with the posterior vesicle. The anterior vesicle is considerably larger than the posterior, and is nearly spherical in shape: but it is flattened on the upper side, where the cæcal process of the membranous vestibule of the ear touches it. The walls of the vesicle are thin and silvery, and are readily separated into their two constituent membranes.

The stalk of this vesicle is conical, the narrower end being posterior; it communicates with the vesicle on the postero-ventral surface of the latter.

The second or posterior vesicle is ellipsoidal, the long axis being vertical; its duct is very short and conical, and its wider end arises from the ventro-internal region of the vesicle.

The anterior vesicle and its duct lie embedded in the pro-otic bone, the posterior and its short duct in the pterotic, while the anterior portion of the common air-duct, with its fusiform swelling, passes through the exoccipital, and the shape of the whole of this system is faithfully reproduced by the dense layer of bone immediately surrounding it.

The bony bulla surrounding the anterior vesicle projects on both the external and internal (cerebral) surfaces of the pro-otic bone, it is very nearly spherical, and has on its internal (upper) surface an oblique pyriform opening, through which the diverticulum of the vestibule passes. This latter dilates immediately inside the bony bulla into a plano-convex chamber, the convex side being applied to the inner surface of the bone, while the flat side is closely applied to a corresponding flattening of the anterior air-vesicle occupying the remaining five-sixths of the bulla.

In a fresh skull, *i.e.*, one which has not been macerated nor allowed to dry, the silvery colour of the air-vesicle can be seen through the semi-transparent bone; and the extent of the vestibular diverticulum can also be seen without breaking open the bony capsule, since its walls are yellower in colour than

those of the air-vesicle, and the position of the septum between the two is marked by a faint line running in a circular manner around the slit-shaped aperture of the bony capsule.

The sutures between the pro-otic, pterotic, and exoccipital meet in a point, and, strangely enough, the short tubular stalks of the air-vesicles and their common duct meet at this same point, and bisect the angles formed by the sutures.

Since these sutures remain cartilaginous and the bony tubes enveloping the ducts get very narrow at the point of union, it is extremely difficult to isolate this system of bony capsules in its entirety.

The posterior vesicle is not in any intimate connection with the membranous labyrinth, but it lies within the loop of the external or horizontal semicircular canal, the course of which can be readily traced around the bony envelope of the vesicle by dissecting the dried skull.

The vesicular stalks are shorter and the vesicles consequently closer together in the young than in the adult.

In the Pilchard, as in the Herring, the position of both air-vesicles can be recognised in the dry skull, but the bony envelope of the anterior vesicle is less prominent on the under side of the skull, while on the upper aspect of the skull the exposed part of the bony capsule of the posterior vesicle is of considerably greater extent and of less curvature than in the Herring.

The ducts of the air-vesicles are of more uniform calibre than in the Herring, being cylindrical rather than conical.

The anterior air-vesicle, instead of being spherical, is greatly elongated transversely, the diameter from right to left being about twice as long as the antero-posterior diameter. The vesicle, also, is slightly narrower at its inner than its outer end, and the duct, which arises from its posterior surface at nearly the middle of its transverse length, runs backwards, and not postero-externally as it does in the Herring, to join the common air-duct (see fig. C, page 32).

The relations of the vestibular cæcum and the pyriform slit on the dorso-posterior side of the bony envelope of the anterior vesicle are the same as in the Herring. The posterior air-vesicle, as mentioned by Matthews,¹ is partially divided into

¹ *Loc. cit.*, p. 288.

two chambers, a large upper and a smaller lower one. The duct springs from the ventral end of the lower chamber, and runs horizontally inwards to join the common duct.

The horizontal semicircular canal of the ear runs in the constriction which separates the upper and lower chambers.

The upper chamber is sub-spherical, and lies above and slightly internal and posterior to the lower.

On the antero-internal surface of its bony envelope is a small perforation, with a distinct smooth circular edge. This perforation is situated in the middle of the anterior vertical semicircular canal, and reminds one forcibly of the crescentic slit in the anterior bony capsule; but it is not traversed by any process of the membranous labyrinth, neither is the wall of the air-vesicle itself at all modified in the vicinity of the perforation.

It is, nevertheless, very interesting, as furnishing a means of putting the wall of the air-bladder in direct communication with the cranial cavity.

In the Sprat the bony capsule of the anterior air-vesicle is very prominent in the dried skull, more so than in the Herring; it is sub-spherical, as in the latter, but is larger in proportion to the size of the skull.

The dorso-posterior aperture through which the vestibular cæcum passes is shorter transversely than in the other forms examined, and is guarded by very prominent lips.

The duct of the vesicle arises from its posterior end and runs straight backwards, and becomes continuous with what corresponds to the common air-duct of the other forms.

The second or posterior vesicle is absent, and Matthews¹ utilises this feature as one of the means of distinguishing Sprats from young Herrings.

In the Anchovy both of the vesicles are present, and are very large in proportion to the size of the skull. Portions of both of the bony capsules of these vesicles are visible on the surface of the dried skull.

The anterior vesicle resembles that of the Pilchard in being elongated transversely to the long axis of the body, but this elongation has gone on even farther than in the Pilchard, so that the right and left vesicles nearly meet in the middle line. The

¹ *Rep. Fish. Bd. Scot.*, 1884, p. 55, Appendices, and Pl. III. figs. 3, 4, 5.

long axis of this vesicle is not strictly transverse, but the outer end is somewhat anterior to that nearer the middle line of the body (see fig. D, page 32). The duct of the vesicle is of very large calibre; it runs backwards from the middle of the hinder surface of the vesicle, and unites with the duct from the posterior vesicle, to form the common duct which tapers rapidly down to a very fine tube running backwards and inwards through the exoccipital bone, from which it emerges behind and runs parallel to the vertebral column for a distance of a quarter of an inch before uniting with its fellow of the opposite side.

The posterior vesicle, although very large, differs from that of the Pilchard in not being constricted into an upper and a lower portion. In shape it more resembles the posterior vesicle of the Herring, but the duct is wider, and there is also a slight flattening on the antero-internal surface.

In the Allis Shad (see fig. B, page 32) the anterior vesicle is much larger than the posterior; it is elongated transversely, and its duct arises behind, and externally to the middle of its transverse length, and not near the middle as it does in the Pilchard and Anchovy; the vertical diameter, also, is greater near the internal than at the external end.

The transverse slit on the dorsal surface of the bony capsule in which this vesicle lies is elongated and nearly straight.

The posterior vesicle is small and not distinctly marked off from its duct, which is conical, the broad end being external and opening upwards and outwards into the vesicle.

In the Thwaite the features of the air-vesicles and their ducts are very similar to those of the Allis Shad, and a detailed description is therefore unnecessary. Among the slight differences which do exist may be mentioned the greater elongation transversely of the posterior vesicle and its slightly smaller size in the Thwaite than in the Allis Shad.

Breschet¹ gives a figure of the bony envelopes of the Thwaite² which exhibits this inequality in the size of the anterior and posterior vesicles, but the anterior is represented as being nearly spherical, and the stalk of the posterior is unnaturally short. Both of these details point to the conclusion that the specimen here figured was not fully grown.

¹ *Loc. cit.*, pl. iv. fig. 3.

² See p. 30.

The Ear.

The membranous labyrinth of the Herring consists of a sacculus and a utricle, with three semicircular canals arising from the latter.

The sacculus is elongated and ellipsoidal in shape, and slopes downwards and inwards from the utricle. The ductus endolymphaticus arises on the inner or cerebral surface, and runs upwards in the thickened fibrous *dura mater*; and Hasse¹ states that it arches over in the very conspicuous thickening of the *dura* on the upper side of the cranial cavity, behind the cerebellum, and unites with the corresponding ductus of the opposite side, thus forming an open communication between the two sacculi. Retzius inclined to the belief that the ductus endolymphaticus ends blindly above as in other Teleosteans. The sacculus contains a very large otolith, the sagitta, and terminates postero-dorsally in a lagena cochleæ with an otolith, the asteriscus. The ventro-external surface of the sacculus lies over a membranous fenestra of the skull-wall, situated between the exoccipital, basioccipital, and pro-otic bones, and described by several authors as a foramen ovale; the sacculus-wall is here separated from the mucous membrane of the mouth by this membrane only.

Retzius² describes, with a certain amount of reserve, a small opening—a canalis utriculo-saccularis—by which the sacculus is in communication with the utricle; but all doubts as to the existence of this aperture may be dispelled by the fact that the sacculus can be injected from the utricle by it.

The utricle, lying above the sacculus, is produced anteriorly into a recessus utriculi, from which arise the ampullate ends of the anterior vertical and the horizontal semicircular canals. The latter canal runs around the second air-vesicle of the swim-bladder in the pterotic bone; the former is mainly enclosed in cartilage, and, uniting above with the upper end of the posterior vertical semicircular canal, descends to the utricle as the median sinus or sinus utriculi superior, which lies free at the side of the cranial cavity. The posterior vertical semicircular

¹ *Anatomische Studien*, 1873, bd. 1, Heft 4, pp. 583–610.

² *Das Gehörorgan der Wirbelthiere*, Stockholm, 1881, vol. i. p. 83.

canal runs through the exoccipital, supraoccipital, and epiotic bones; its posterior end is dilated into an ampulla, and its upper end opens, as before mentioned, into the upper end of the median sinus. Breschet¹ has described and figured in the Shad a "commissure auditive supérieure" passing across in the down-growth of the dura mater behind the cerebellum, and immediately in front of the horizontal suture between the supraoccipital and exoccipital bones, and putting the upper ends of the two median sinuses into open communication. It will thus be seen that the middle part of this transverse canal has exactly the same position as that described by Hasse; but Breschet's canal is inserted near the top of the median sinus of each side, while Hasse's canal runs down to the sacculus. On opening the fresh head there certainly appears to be a canal arching over from one median sinus to the other, and having the same colour as the semicircular canals; but on dissecting out the labyrinth, the supposed supracerebral canal can be removed without leaving a scar. Weber makes no mention of any supracerebral canal, and Retzius acknowledges his inability to recognise either Breschet's or Hasse's superior commissure. In only three cases (two Pilchards and one Herring), out of about forty injections, have I been able to pass coloured medium into this supracerebral canal. In these cases the canal appeared to conform to Breschet's description rather than that of Hasse's; but unfortunately these three injections cannot be regarded as conclusive, since the medium may have escaped from the labyrinth into the perilymphatic spaces.

Renewed investigations, devoted to the elucidation of this one point, are necessary to decide whether this supracerebral canal contains endolymph and opens into the interior of the membranous labyrinth of each side, and if so, whether it is a constant feature or only occurs occasionally as an individual variation, or whether it contains perilymph and only becomes injected by the rupture of the wall of the labyrinth or some similar mishap.

The recessus utriculi sends antero-ventrally a blind cæcum, which passes through the dorso-posterior aperture in the bony capsule of the anterior air-vesicle, situated immediately below

¹ *Recherches sur l'organe de l'ouïe des Poissons.* Paris, 1838, p. 17.

the recessus, and dilates suddenly into a convexo-plane chamber, the convex surface of which is closely applied to the bony wall of the capsule, the flat surface being in close contact with a corresponding flattening of the anterior air-vesicle which occupies the remainder, about five-sixths or more, of the bony capsule, so that the united flat walls of the utricular cæcum and the air-vesicle act as a sort of tympanic membrane, through whose agency the varying degrees of pressure of the gaseous contents of the swim-bladder and of the viscid endolymph react upon each other.

Coloured injecting medium (*e.g.*, finely-ground indigo or carmine suspended in weak gum-water), passed into the labyrinth by one of the semicircular canals, can frequently be made to enter this cæcum; but as the neck is somewhat small, and there is no means of escape of the contained endolymph, success cannot be assured in every experiment.

Stannius,¹ Owen,² and Günther³ give short descriptions of this cæcum, apparently culled from Weber, who first described it.

Its presence is contested by Hasse, and Retzius apparently denies its existence. Breschet was evidently of the opinion that this utricular cæcum did not enter the bony capsule, but simply closed over the aperture on its dorso-posterior surface, for on p. 14 he says, "Le point du globe osseux qui est percé de cet orifice est convert par une partie du vestibule membraneux et par des filets nerveux;" and again on p. 17, "Sa partie antérieure repose sur le globe osseux antérieur." There are several passages in the *Histoire Naturelle des Poissons* denying any connection between the ear and air-bladder, but Valenciennes' error was due in a great measure to assuming, in the first instance, that previous anatomists had described an *open* communication between the two organs, and as in his experiments he failed to pass injection media from the air-bladder to the membranous labyrinth or the cranial cavity, he hastily concluded that the previous descriptions were incorrect. Thus, on page 4, vol. xx., he says, referring to the air-ducts of the Herring, "Ce sont eux

¹ *Lehrbuch der vergl. Anatomie*, 1846-48, vol. ii. p. 83.

² *Comp. Anat. and Phys. of Vertebrata*, 1866, vol. i. p. 346.

³ *Study of Fishes*, Edin. 1880, p. 117.

que quelques anatomistes ont pris pour des tubes de communication entre la vessie aérienne et l'oreille interne;" and again on page 40, "Presque tous les anatomistes se sont trompés sur ce ligament, et qu'ils l'ont considéré comme un petit canal creux servant à établir une communication entre la vessie aérienne et l'intérieur de l'oreille. Je me suis assuré par tous les moyens anatomiques qui peuvent être employés, que cette communication n'existe pas plus dans le Hareng que dans la Sardine ou dans l'Alose. Aucune injection n'a pu passer de la vessie dans la boîte cérébrale. J'ai ouvert le crâne d'un hareng, et le sac de l'oreille d'un côté, et j'ai enlevé entièrement celui de l'autre côté. J'ai rempli d'air la vessie en l'injectant par l'estomac. Pas une bulle d'air ne s'est échappée de l'organe."

On the external surface of the recessus utriculi, arising a short distance behind the cæcum just described, and in front of the ampulla of the anterior vertical semicircular canal, is a second and larger cæcum, of the form of a three-sided pyramid, whose apex points outwards and forwards, and the anterior face of which is narrower than the other two. This chamber lies between the anterior and posterior vesicles, and partially fills the space between the pro-otic, pterotic, sphenotic, and alisphenoid bones; it opens into the recessus by a relatively large aperture, and is readily injected from the utriculus.

The discovery of this cæcum is apparently due to Breschet, who includes it in his figure of the membranous labyrinth of the Thwaite, and calls it the "bulbe accessoire," but he is seriously in error in regarding it as a rudiment of the cochlea, for it is situated at the anterior end of the utriculus instead of at the posterior end of the sacculus, and, moreover, the lagena cochleæ is present in the Clupeoid ear in its normal position.

On the inner side of the recessus utriculi, opposite the ampulla of the anterior vertical semicircular canal, arises a canal, about 1 mm. in diameter, which runs transversely in the dura mater under the brain, and forms an open communication between the two vestibules, so that injection mass thrown into the semicircular canal of one ear will pass across to the ear of the opposite side. This transverse canal lies just behind the pituitary fossa; its anterior edge is nearly straight, but the posterior is somewhat irregular, so that the diameter of the canal

varies at different places. This duct of communication of the two vestibules was first discovered by Weber in the Herring, and was afterwards found by Breschet in the Shad, and it seems strange that, with these descriptions before them, two such careful investigators as Hasse and Retzius should fail to recognise it.

In conclusion, it may be stated that the above remarks on the membranous labyrinth apply more especially to the Herring and Pilchard; the Allis and Thwaite Shads were also examined and found to be similar, but the Sprat and Anchovy were not examined, on account of the practical difficulties in the way of injecting the labyrinth, without which no definite statement can be made as to the transverse canals and utricular cæca.

My grateful acknowledgments are due to the Committee of the British Association for the Advancement of Science for placing at my service a table in the Plymouth Laboratory of the Marine Biological Association, during the months of August and September of the past year.

My thanks are also due to Dr G. H. Fowler, Director (*pro tem.*) of this Laboratory, for his assistance and untiring efforts in maintaining a constant supply of material, to G. Butler, Esq., for some well-preserved specimens of the Mediterranean Anchovy, and to Professor G. B. Howes for valuable suggestions and advice.

THE PECTINEUS MUSCLE AND ITS NERVE-SUPPLY.

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I. *The Pectineus Muscle*.—One of the chief points of interest attaching to the pectineus is the fact that it may be innervated by two morphologically distinct nerves, the anterior crural and obturator; and also from a third source, the so-called accessory obturator nerve. It is a matter of some importance, in relation to the homologies of particular muscles, and to the question of the constancy of the nerve-supply of muscles generally, to attempt an explanation of this peculiarity, which, among the muscles of the limbs, is only shared by two others; the *brachialis anticus* (musculo-cutaneous and musculo-spiral), and the *biceps flexor cruris* (1) (internal and external popliteal), being the only other muscles supplied by both dorsal and ventral series of nerves.

The human pectineus is a muscle which presents few abnormalities, and is for the most part simple in its character. It occasionally consists, however, of two incompletely separated strata, of which the outer is supplied by the anterior crural, the inner by the obturator nerve (2). Henle (3), indeed, describes and figures the origin of the muscle as constantly occurring from two separate slips, which unite together before reaching their insertion. He gives the nerve-supply of the muscle as the anterior crural, and occasionally the obturator nerve.

In many Mammals, as in the horse (4), the muscle is divided into two parts, separated from one another by the pubi-femoral ligament; a superficial portion, innervated by the anterior crural nerve, and regarded as homologous with the human pectineus; and a deeper portion, supplied by the obturator nerve, and looked upon as a part of the adductor longus muscle.

In *Cryptobranchus Japonicus*, moreover, Humphry (5) describes the pectineus as "separated from the middle or adductor portion of its stratum by a prolongation of the tendon of the

external oblique, which extends from the spine of the pubes, along the anterior margin of the pubes to the hip-joint." He regards the muscle as forming part of the plantar stratum of muscles, but, at the same time, as morphologically continuous with the iliacus internus. It is innervated by the anterior crural nerve.

Gadow, in his admirable memoir on the muscles of the hind limbs of reptiles (6), describes with the greatest clearness the condition of the muscle, and enters fully into the question of its homologies in Birds and Mammals. It represents apparently part of the *pubi-ischio-femoralis internus*, a large muscle which is generally divided into three parts. Two of these parts, as a rule, correspond to the pectineus, and one to the ilio-psoas. Considerable differences, however, are met with in the condition of the muscle, and in its innervation in the different groups of Reptiles. In *Crocodylia* the two parts representing the pectineus are innervated by the obturator nerve; the part homologous with the ilio-psoas by the anterior crural. In *Chelonia* one of the portions homologous with the pectineus is absent; the remaining two parts of the muscle are both supplied by the anterior crural nerve. In *Sauria* the entire mass is supplied by the anterior crural nerve; but the arrangement is peculiar, and throws an interesting light upon the matter in hand. Parts I. and II. (=pectineus) are supplied by the anterior crural nerve; Part III. (=ilio-psoas) "receives a small nerve out of the plexus cruralis, which may separate *early* from the anterior crural nerve, as in *Monitor*; or it may separate late, as in *Cyclodus*, in which case it comes from the obturator, *but before its passage through the foramen.*"

Without entering further into the question of the homologies of the muscle, there appears little doubt that it may consist of elements belonging to two separate muscle-masses. On the one hand, it is to be associated mainly with the group of (dorsal) muscles represented in man by the iliacus, sartorius, and quadriceps extensor, both in morphological position and in innervation. On the other hand, the occasional appearance of a separate deeper layer, and the occasional innervation of the muscle from the obturator nerve, the constant presence of two strata in certain mammals innervated from separate sources, and the conditions met with in reptiles, lead one to infer that

in some cases there is included within the pectineus muscle a portion belonging probably to another and morphologically separate (ventral) muscular stratum.

II. *The Nerve-Supply of the Pectineus.*—If this inference be a correct one, the explanation becomes possible of the otherwise anomalous fact that the pectineus receives its nerve-supply from two morphologically distinct nerves. Each supplies that portion of the muscle with which it is phylogenetically related, the anterior crural supplying the constant (dorsal) part of the muscle, the obturator being the nerve for the occasional adductor (ventral) portion.

The matter, however, is complicated by the presence, in certain cases, of the accessory obturator nerve. This nerve was first described by Winslow (7), who named it *n. accessorius anterioris cruralis*. Schmidt, later, described it in great detail, and suggested the name which it now bears, on account of the fact that, when present, it invariably communicates with the obturator nerve. It was found by Schmidt (8) in four or five out of nine or ten cases, and presented variations both in origin and distribution. In five figures of the lumbar plexus the origin of the nerve is shown; in three cases it arose from the third nerve, and in two from the third and fourth. When large the nerve supplied the usual three branches: one to the pectineus, one to the hip-joint, and one to communicate with the obturator nerve. When the nerve was smaller the branch to the pectineus was absent. (Schmidt does not mention by what nerve the pectineus was supplied in these cases.)

Three Cases of Accessory Obturator Nerve.—Out of twenty subjects which I have recently examined, with special reference to the nerves of the lower extremity, this nerve was present in three cases—two adults and one foetus of eight months. In all it was present on both sides, and had a similar origin and distribution. It arose (fig., *Acc. Obt.*) from the front of the root of the anterior crural (*A.c.*), which was derived from the third lumbar nerve, and was behind and altogether independent of the root of the obturator (*Obt.*) springing from the same source. It coursed through the psoas muscle along with, but easily separated from, the obturator nerve; after emerging from the inner border of the muscle it passed downwards along the pelvic

brim, beneath the external iliac vessels, and leaving the obturator nerve it entered the thigh in front of the pubis. Here the larger part of the nerve supplied the pectineus muscle

along its outer border; one small branch entered the hip-joint, and another communicated beneath the pectineus with the superficial part of the obturator nerve.

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In these three cases the accessory obturator was the only nerve to the pectineus. In the remaining seventeen cases the muscle was supplied by the anterior crural, and in none (although the point was carefully investigated) was the obturator nerve traced into it. In several cases it was noticed that the branch from the anterior crural nerve to the pectineus sprang from the main trunk within the abdomen, and

A

Ant. Cr.

Obt.

pursued an independent course beneath the large vessels into the thigh.

The points of interest associated with the accessory obturator nerve are—(1) that its origin is more closely associated with that of the anterior crural than that of the obturator nerve; (2) that in its course it accompanies the obturator nerve for a certain distance, and then enters the thigh by passing over the pubis; (3) that it supplies (a portion of) the pectineus *in place of* the anterior crural nerve.

The anterior crural and obturator nerves are morphologically distinct and separate, both in origin and distribution. In their passage to the lower limb they are separated from one another by the interposition of the pubic bone, just as the sacral portion of the lumbo-sacral plexus is separated from both of them by the articulation of the ilium and sacrum. A nerve, therefore, which passes over the pubis to the thigh is more

intimately related to the anterior crural than to the obturator nerve. Moreover, the constant (dorsal) position of the pectineus is always supplied by such a nerve, either directly from the anterior crural or indirectly from the accessory obturator.

III. *Conclusions*.—Taking all these statements into account, one is led to conclude that the term *accessory obturator* is a misnomer, and that the name *accessory anterior crural* would be a more correct designation, on the ground that the nerve is really a detached portion of the anterior crural nerve. (There is nothing significant in its final communication with the obturator nerve. That, on the other hand, is rather an additional reason for regarding it as derived from the anterior crural nerve, as in the "obturator plexus" there is a constant anastomosis between these two nerves.)

The facts adduced seem also to support the view of the innervation of muscles generally in a manner which is really not variable, but which is in accordance with a definite morphological plan. Such a muscle as the pectineus, which may contain elements of both dorsal and ventral muscular strata, may receive two different nerve supplies. The dorsal stratum, constantly present, is supplied through the dorsal nerve trunk (anterior crural or accessory obturator); the ventral stratum, when present, is supplied by the ventral trunk (obturator). The absence of the latter nerve seems to be a consequence of the absence of the part of the muscle derived originally from the stratum innervated through the medium of that nerve.

LIST OF PAPERS, &c., REFERRED TO.

1. "On the Morphology of the Sacral Plexus in Man" (Paterson), *Studies from the Anatomical Department, The Owens College*. Note.
2. Quain's *Anatomy*, vol. i., 9th edition.
3. Henle's *Anatomy*, vol. i. p. 268.
4. Chauveau's *Comparative Anatomy of the Domesticated Animals*, Tr. Fleming, p. 289.
5. Humphry's *Observations in Myology*, p. 20.
6. Gadow, "Beiträge zur Myologie der hinteren Extremität der Reptilien," *Morpholog. Jahrbuch*, Bd. vii.
7. Winslow, *Exposit. Anatom. Tract. de nervis*.
8. Schmidt, J. A., *De nervis Lumbalibus eorumque plexu Commentarius*, Vindobonæ, 1794.

SOME VARIETIES OF THE LAST DORSAL AND
FIRST LUMBAR NERVES. By MONTAGU GRIFFIN,
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Dublin.*

THE variations which occur in connection with the distribution and arrangement of the last dorsal and first lumbar nerves formed one of the subjects which were recommended last year by the Anatomical Society for collective investigation in the different schools of Anatomy throughout the country. At the request of Professor Cunningham, I undertook to carry out this part of the work in the Anatomical Department of Trinity College. We found, as indeed we had anticipated, that the subject was not one which lent itself readily to this form of investigation. Its pursuance interfered considerably with the routine work of the dissecting-room, and in the case of each nerve five different examinations were rendered necessary by changes in the position of the subject and the very different stages in the dissection of the back, lower limb, and abdomen at which the nerves were exposed. Further, it is not possible to arrange advantageously the results obtained in tabular form. The return, therefore, which I have submitted to the Secretary of the Collective Investigation Committee cannot be regarded as giving a full account of the results of the work, and as certain of these in a somewhat more expanded form are of considerable interest from a descriptive point of view, I have been asked by Professor Cunningham to embody them in the present paper.

I have examined the nerves in question in fifty subjects, and in seven cases I was permitted to trace them throughout their entire course at one time and by one dissection. In the majority of cases, however, I had to wait until, in the ordinary course of the dissection of the subject, the stage at which the nerves are exposed in the different regions were reached. I know that my work entailed considerable inconvenience to the dissectors of these parts, and I owe to these gentlemen my best thanks for the ready assistance which they afforded me.

The plan which I adopted was to carefully note the description which is given of these nerves in our standard text-books, and then in each dissection I recorded simply those points in which the nerves exposed differed from this.

Last Dorsal Nerve.—The anterior primary division of this nerve is very constant in its relations and distribution. It seldom deviates from the condition described in our standard works on anatomy. In one subject, from its commencement to its termination, it played the part of the ilio-inguinal, and in every particular, save its origin, it presented an arrangement identical with that nerve.

In four subjects the lateral cutaneous branch of the last dorsal nerve was completely absent. In these cases the place of this branch was taken by an unusually large iliac branch of the ilio-hypogastric.

Three points may be added to the usually accepted description of this nerve—(1) its anterior branch supplies several twigs to the internal oblique; (2) its lateral cutaneous branch emerges close to the anterior border of the latissimus dorsi muscle, and 3 inches above the iliac crest; and (3) the lateral branch, before piercing the external oblique muscle, invariably supplies to this muscle a large and constant offset.

The *posterior primary division* of the last dorsal nerve presents the typical arrangement of the corresponding part of the other spinal nerves. The sudden downward sweep of these nerves is very noticeable, and likewise the consequent fact that the respective areas of skin supplied by them are at a lower level than the corresponding areas supplied by the anterior divisions. Drs Wardrop Griffith and Oliver have already called attention to this in a suggestive paper in the *Proc. of the Anatomical Society*.¹ The precise area of skin supplied by the posterior primary branch of the last dorsal nerve is situated between the back part of the crest of the ilium and the middle line.

Ilio-Hypogastric Nerve.—The hypogastric or abdominal branch of this nerve has been differently described by different authors. Quain states that it supplies both transversalis and internal oblique muscles, whilst Macalister considers that it is entirely sensory. I have not been able to find any twigs to

¹ *Journ. Anat. and Phys.*, Jan. 1890, xi.

muscles from this branch except in one case, to be presently described, where it furnished the nerve of supply to the pyramidalis muscle.

I have twice seen a plexiform communication between it and the ilio-inguinal. This constituted a delicate interlacement of fibres which lay on the transversalis muscle in front of and above the anterior superior iliac spine. The point of exit made by the hypogastric branch through the fascia of the external oblique was constant, inasmuch as it took place on a line drawn vertically upwards from the mid-point of the outer margin of the external abdominal ring. Its point of emergence on this line, however, varied from 2 to $2\frac{1}{2}$ inches above the level of the spine of the pubis. The exact normal cutaneous supply of this branch I have been unable to discover accurately. To judge from the downward tendency of its branches, I should say that Quain's description, namely, that the nerve supplies the skin for 2 inches above the pubis, is nearest the truth. I have not seen any offset from it distributed as high as the umbilicus, as Macalister has stated.

The lateral cutaneous (iliac) branch of the ilio-hypogastric I found to be very constant, both in its position and area of supply. In every case in which it existed (48 out of 50) it crossed the tubercle on the iliac crest as mentioned by Ellis, and in one subject it was placed so deeply that it grooved the bone in the manner described by the same authority. The position of this tubercle on the iliac crest, and consequently the point at which the nerve crosses the bone, is very much as Macalister has described, viz., the anterior point of the trisection of the crest of the ilium. It is immediately above this that the nerve pierces the attachment of the external oblique muscle. The text-books describe the point at which this nerve pierces the internal oblique as being the same as its point of emergence through the external oblique. This I found to be not quite correct. It pierces the internal oblique shortly after it is given off by the main trunk of the nerve; consequently the nerve, before becoming superficial, lies for a certain distance between the two oblique muscles. It forms at times a network of communication above the iliac crest, with the lateral cutaneous offset of the last dorsal nerve. In the four cases in which the lateral

cutaneous branch of the last dorsal did not exist, the lateral cutaneous branch of ilio-hypogastric was very large. There was in this case a large and more posterior branch, which formed a free and complicated network of communication with the external cutaneous branches of the posterior primary divisions of the second and third lumbar nerves. In investigating the ultimate distribution of the cutaneous filaments of this nerve I never failed to observe one branch supplying the skin over the tensor fasciæ femoris muscle as far as its anterior border. I find that Krause has described this branch: "N. ilio-hypogastricus. Ersetzt häufig den ilio-inguinalis ganz oder theilweise. Gibt zuweilen einem hautast der in die den M. tensor fasciæ latae deckende cutis hinabreicht."¹ The other cutaneous branches supply the skin over the gluteus maximus to an extent that varies in proportion to that of the other cutaneous nerves in the region, but which, to judge from the few and rough observations which I have been able to make, supply the integument over the outer third of the gluteus maximus and medius muscles, as far as the level of the great trochanter.

The Ilio-Inguinal.—In eight out of the fifty cases examined, the ilio-inguinal arose as a combined nerve with its fellow, the ilio-hypogastric, from the first lumbar nerve. This lacks one case to make up the 18 per cent. stated by Macalister as the percentage in which these nerves arise in common. In *one* case the ilio-inguinal arose from the second lumbar. Gegenbaur mentions this variety.

In those cases in which the ilio-inguinal and ilio-hypogastric arose in common, the division occurred close to the point where the branch representing the ilio-hypogastric pierced the internal oblique. Previous to this the combined nerve follows the course usually taken by the ilio-hypogastric. In one case the ilio-inguinal did not exist; the genital branch of the genito-crural taking on itself the part of the ilio-inguinal in its final distribution. Krause notices the converse to this abnormality. "The ilio-inguinal sometimes compensates the genito-crural," he states; and then he adds: "It sometimes descends to the thigh behind Poupart's ligament, winds round the saphena vein, and turns back to its normal distribution-area under the external abdo-

¹ Krause, *Anatomie*, vol. iii. p. 210.

minal ring. Scrotal or labial branches may fail." I have not observed any of these conditions.

In two subjects very abnormal conditions existed. In one of these the ilio-hypogastric did not exist; the ilio-inguinal arose normally, but passed down over the iliacus muscle in the exact position which the external cutaneous nerve should occupy. Having reached Poupart's ligament on each side of this subject, an inch in front of the anterior superior spine, the nerve pierced the abdominal muscles in the usual manner, passed through the inguinal canal, and gave off its two usual branches of distribution. The external cutaneous nerve proper did not exist. On the left side of this subject previous dissection had rendered it impossible to determine from whence an external cutaneous supply for the thigh had been derived. On the right side, however, an external cutaneous branch was given off by the anterior crural nerve. This variety is not uncommon.

In the second case the same anomaly existed, with some further variation. The ilio-hypogastric and external cutaneous nerves were again absent. The ilio-inguinal nerves arose normally, but again occupied the position of the external cutaneous nerves as they crossed the iliacus muscle. In this subject, however, the ilio-inguinal not only took the position of the external cutaneous nerve in the pelvis, but also gave off a branch which performed the functions of that nerve in the thigh. An inch below the anterior superior spine of the ilium it sent a branch *over* Poupart's ligament, which supplied the skin on the outside of the upper two-thirds of the thigh. The rest of the nerve passed on by its normal course to its usual distribution.

Nerve Supply of the Pyramidalis Muscle.—I have reserved the question of the nerve supply of the pyramidalis muscle until now, seeing that the result of the investigation involves the three nerves from which this supply might reasonably be expected to come. I have been able to verify the nerve supply of this muscle in only *seven cases*. In others, where the nerve was found, previous dissection had destroyed its connections. When discovered, it was always by the adoption of one method. The sheath of the muscle was opened; the apex of the muscle was detached from the linea alba, and it was then reflected downwards. During this process I carefully searched for

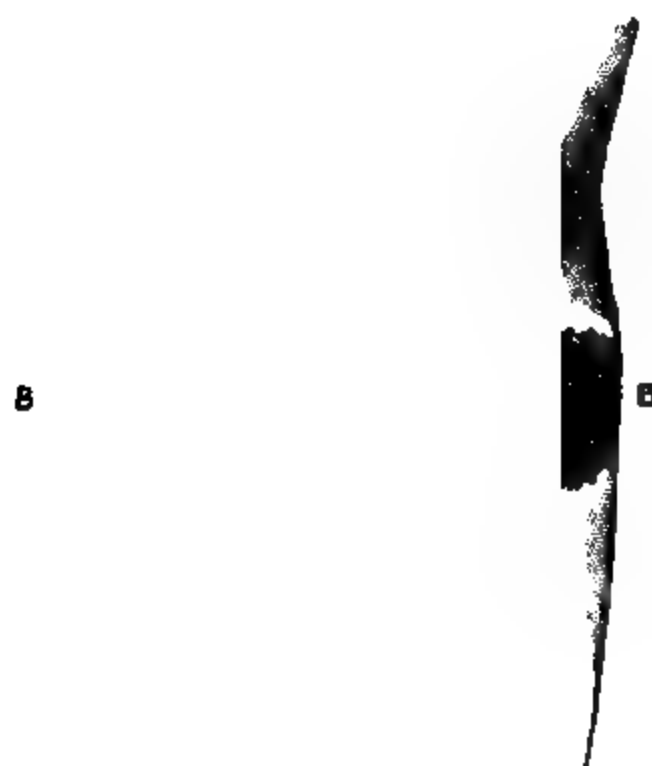
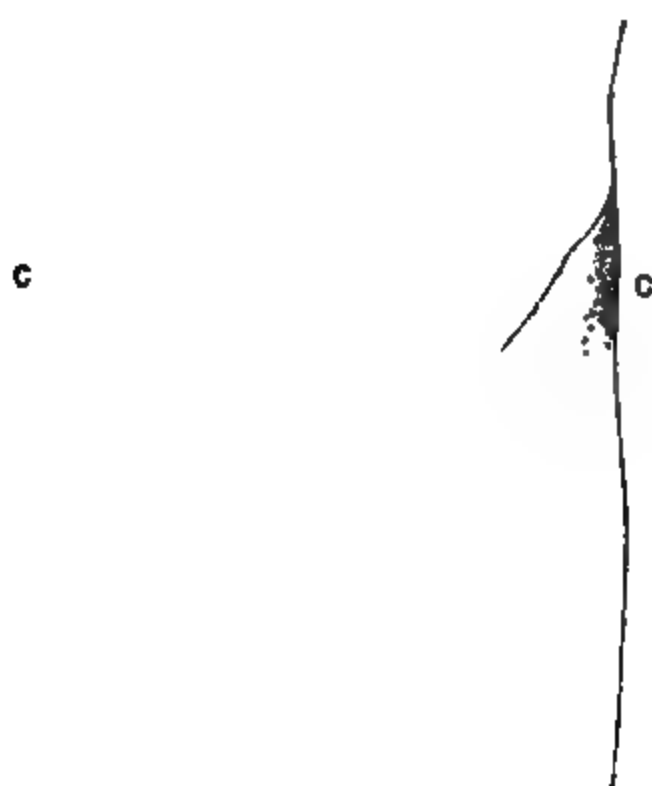
any filament of nerve entering its posterior surface. The first nerve of supply which I found entered its posterior surface, and when traced outwards it was proved to come from the ilio-hypogastric. This nerve of supply was present on both sides of the subject, and it passed inwards behind the external pillars of the external abdominal ring. The remaining six nerves of supply which I found came from the last dorsal nerve. Five of these pierced the substance of the rectus abdominis muscle, and supplied the pyramidalis about the middle of its posterior surface. The last nerve supply which I found, at first sight appeared to verify the condition which Ellis has described as the normal—namely, that the pyramidalis muscle obtains its innervation from the ilio-inguinal. The branch in question arose from a nerve which was performing the functions of the ilio-inguinal. It passed upwards out of the inguinal canal, and from thence behind the pillars of the ring, and finally entered the posterior surface of the muscle. Further investigation of this subject, however, proved this nerve to be the one case in which the last dorsal had taken the place of the ilio-inguinal nerve. It was as if, having gone on an unwonted errand in supplying the inguinal region, it suddenly recollected itself, and sent back a branch to perform what appears to be one of its normal duties—the nerve supply of the pyramidalis.

My results, therefore, are opposed to the statements made on this subject by Ellis. I find, however, that the result, so far, is supported by the German investigators. Krause¹ takes the lower five dorsal nerves together, and states that the pyramidalis receives its supply from this group: from which of them he does not mention. Aeby follows Krause in his method of description, and corroborates him as to the innervation of the pyramidalis. Schwalbe,² in describing the last dorsal, says: "Also the musculus pyramidalis may become supplied by the last intercostal nerve; whether the first lumbar nerve shares in its innervation requires a renewed investigation." The above-mentioned case, in which the ilio-hypogastric supplied the muscle, is an instance of the first lumbar nerve giving it a supply.

In conclusion, I would draw attention to a peculiarly instruc-

¹ *Anatomie*, p. 899.

² *Nervenlehre*, p. 943.



M. G. 30

The upper figure gives the ventral, the lower the dorsal aspect of the case of herpes referred to in the text. The patient was seen in the dispensary of Sir Patrick Dun's Hospital, Dublin, October 12th, 1890.

tive case of Herpes Zoster which came under my notice. The affected areas seem to be singularly suggestive of the cutaneous distribution of the first lumbar nerve, a type which Bristowe has named "Lumbo-Inguinalis."

A glance will show that "zonular" is the last word that can be applied to this type of the disease; yet it becomes evident that this is owing to the fidelity with which the disease followed the cutaneous distribution of the first lumbar nerves. The affected areas of skin, A.A., represent the cutaneous supply from the posterior primary divisions of the first lumbar nerves; B.B., the lateral cutaneous or iliac branches of ilio-hypogastric; C.C., the branches over anterior border of the *tensores fasciæ femoris*; D.D., the hypogastric cutaneous termination; and E.E., the terminal cutaneous supply to the skin of the scrotum and thigh furnished normally by the ilio-inguinal nerve.

A SIMPLE METHOD OF FIXING PARAFFIN SECTIONS TO THE SLIDE. By G. LOVELL GULLAND, M.D., F.R.C.P.E.

(From the Laboratory of the Royal College of Physicians, Edinburgh.)

IN Dr Gaskell's interesting paper "On the Origin of Vertebrates from a Crustacean-like Ancestor" (*Quart. Jour. of Mic. Sci.*, vol. xxxi. 1890), he describes a method (on p. 382) by which he succeeded in overcoming the folding of sections of the cranium of *Ammocoetes*. It consists in floating the series of sections on the surface of warm water, which flattens them, and then transferring them to the slide, which has previously been coated with albumen and glycerine. The sections are then dried by pressure between blotting-paper, the wax is melted, removed by xylol, and the sections are then mounted in Canada balsam.

For some time before Dr Gaskell published this method I had been using it, and had experimented with several modifications of it; one of these has been so successful in my hands, and in those of others to whom I have communicated it in this laboratory and other laboratories in Edinburgh, that I am desirous that it should become more widely known.

In using albumen and glycerine as a fixative, according to Mayer's method, which is, I suppose, the way in which Dr Gaskell employs them, I have met with objections which made me wish to omit that part of the process. These difficulties are:—That it is not always easy to get the layer of albumen and glycerine of equal thickness all over the slide, so that the sections do not lie quite flat; that patches of coagulated albumen sometimes retain stains, especially some of the anilines, in a disturbing manner, and this inconvenience, I am told, is specially felt in microphotography; that in manipulating sections on the slide, solutions of picric acid, moderately strong alkaline solutions, and some other fluids cannot be used, as they loosen the adhesion of the section to the slide. Further, I have found, in using Dr Gaskell's method, that if a very large

number of sections are to be mounted on one slide, the fixative is apt to be washed off; and if one trusts to the fixative afterwards, and proceeds in the usual way as described by him, some of the sections may be lost. The method I use is the following:—

The piece of tissue is imbedded in paraffin in the usual way, and I will suppose that a complete series of sections is desired, and is to be cut with the Cambridge rocking microtome. The paraffin block containing the tissue must be trimmed very carefully, care being taken to see that the surface meeting the razor is exactly parallel to the opposite surface, and that the block is exactly rectangular. A thin layer of soft paraffin is then applied to the surface meeting the razor and to the opposite surface—this is best done by dipping these surfaces into the melted soft paraffin,—and when this has become firm, the surfaces are again trimmed square. The reason for this very special care is that any curve in the ribbon, produced by neglect of this precaution, is accentuated by the flattening out of the sections, and though in mounting several ribbons on one slide a slight curve does not matter, and can, indeed, be corrected by folding up the soft paraffin between the sections, a sharper curve of course interferes with the regular disposition of the series. When all the sections required have been cut, the ribbon must be divided with a sharp knife into lengths corresponding to that of the slide in use. A very convenient size is a slide of 4×2 inches with a cover-glass of $3 \times 1\frac{1}{2}$ inches. These ribbons are then to be seized at one end with forceps, and the other end is gently lowered on to the surface of the warm water, and as the sections flatten out they will be found to move along the surface of the water, so that more and more of the ribbon can be lowered. It is not so satisfactory to hold both ends of the ribbon and lower the middle first. When the flattening is complete, the slide, carefully cleaned, is immersed in the water, the ribbon is floated into its position on the slide with a stiff brush, and the process is repeated with one ribbon after another until the slide is full. With a little practice one soon learns how to bring the rows close together so that no space is wasted. The slide is then set up on end to allow the superfluous water to drain off.

The best dish for carrying out this process is, perhaps, a flat glass dish standing on a dark table, as the manipulation is more easily accomplished when the white paraffin is thus thrown up in relief. The temperature of the water is of course important, but as different workers use paraffins of varying hardness, no absolute rule can be laid down. It should be comfortably warm to the hand, but never so warm as to melt the soft paraffin holding the sections together. Short of this, however, the warmer the water the more rapidly and completely are the sections flattened.

So far the sections are simply lying loose upon the slide, and they have yet to be fixed to it. This is done by evaporating the water from the surface of the slide. The evaporation might be carried out in many ways, but I shall best explain it by describing my own practice. I almost invariably use paraffin for imbedding whose melting-point is 52° C., and the imbedding oven, an ordinary copper one, is therefore kept at about 54° C. or 55° C. The slides, after the water has drained off as much as possible, are placed on the top of the oven, where the temperature is probably a little under 50° C., and where, consequently, the paraffin of the sections is not melted, though the water rapidly evaporates. The slides are kept there, with a cardboard cover over them to keep off dust, until the evaporation is complete, and the sections have adhered to the slide. The time required for this varies, as I shall show immediately; but the important point is that the paraffin must never be melted until the last trace of water has disappeared from the slide. If this premature melting happens by any accident, the sections are certain to peel off later. When the water has evaporated completely, the opacity of the sections disappears, they become much more transparent, and they look dry. A very few experiments enable one to be sure of the point when slides are safe. Of course when the paraffin used for imbedding is of a lower melting-point than 52° C., the temperature for evaporation must also be lower; and when the oven is regulated as above, this can be managed by putting a few thicknesses of paper under the slide.

When the fixation is complete, the paraffin is melted by putting the slide inside the oven for a little, and is then washed off with turpentine or xylol; and, if the piece of tissue has

been stained *en bloc*, the sections can be mounted at once in balsam.

One of the great advantages of this method is the perfect ease and safety with which it allows sections on the slide to be manipulated, so that the most various stains and reagents can be applied successively to a slide, *e.g.*, the complicated processes used to demonstrate bacteria in the tissues can be applied, with the certainty, moreover, that there is nothing on the slide to be stained which was not in the section.

The time required for complete fixation varies in dependence on several circumstances, but of these the most important are the thoroughness with which the superfluous water has been drained off the slide, and the thickness of the sections. For instance, sections cut with five teeth of the rocking microtome require generally about an hour to dry in the way I have described; those cut with ten teeth perhaps three hours; while those cut with fifteen teeth take six hours, or even longer. This scale is only approximate, and it may be said, generally speaking, that the longer the slide is allowed to dry the better will be the fixation, and, of course, no harm is done to the section by leaving it for an indefinite time in paraffin, so long as the paraffin is not melted.

Of course a single section is to be mounted in the same way as a series, and it will be found that where it is desirable to examine a few sections with as little delay as possible, warm methylated spirit, or even absolute alcohol, evaporate more rapidly than water, while the fixation is as perfect with them, and the method of use exactly the same, as with the less volatile liquid. For obvious reasons these fluids are not likely to be used frequently with long series of sections.

A PAIR OF SUPERNUMERARY TEETH IN THE MOLAR REGION. By Prof. Sir WILLIAM TURNER.

I HAVE on former occasions recorded the presence of single supernumerary teeth in the human dentition. In this *Journal*, vol. xii. p. 142, I described a supernumerary conical incisor, apparently mesial in position, in the upper jaw of a living man. In my account of Human Crania (*Challenger Reports*, part xxix., 1884) I described (p. 30) in a young Australian skull a palatal tooth in the left superior maxilla close to the mesial suture, and in an adult Australian (p. 33) a tooth with two cusps immediately behind the left upper wisdom tooth. I have recently met with an example of a pair of supernumerary teeth in the upper jaw, a condition which from its rarity it may be of interest to put on record.

In July 1891, I received from a former pupil, Mr J. Brown Lester, M.B., as a donation to the craniological collection in the Anatomical Museum of the University of Edinburgh, a set of seven African skulls without the lower jaws, which he had collected in the region of the Gambia. One of these furnished an interesting example of a pair of supernumerary teeth. It was the skull of a Combo native, and was collected in the Gunjur village, Mandingo country.

In each superior maxilla a supernumerary tooth was present in the molar region, and was situated opposite and internal to the interval between the first and second permanent molars. The supernumerary teeth on opposite sides varied materially in shape. The left one was a simple tooth with a conical crown and single fang. The crown was 5 mm. long, and 4 mm. in antero-posterior diameter; its apex was almost on the same plane as the cusps of the molars between which it was situated. The fang projected 4 mm. beyond the edge of the alveolus. The right supernumerary tooth was definitely bicuspidate, and the cusps were placed one in front of the other, and not internal and external as in the proper bicuspid teeth. So much of the fang as was visible without extracting the

tooth, was flattened and not bifid. The antero-posterior diameter of the crown was 8 mm. and its transverse diameter was 6 mm. The cusps were on the same plane as those of the neighbouring true molars. The skull was apparently that of a young woman, for though the basi-cranial synchondrosis was ossified, the sutures of the vault were distinct, and the cusps of the teeth were very little worn. All the permanent teeth were erupted and there was no displacement. The hard palate was distinguished by its remarkable depth, which in more than one locality measured as much as 20 mm.

THE DIRECT ACTION OF HYDROGEN SULPHIDE,
HYDROGEN SELENIDE, AND HYDROGEN TEL-
LURIDE ON HÆMOGLOBIN. By M. A. ARTHMAN
BRUÈRE, M.D.

(From the Physiological Laboratory, University of Edinburgh.)

FROM the researches of Eulenberg, Hoppe-Seyler, and others it is known that hydrogen sulphide exerts a special action on hæmoglobin, resulting, among other changes, in the formation of a chemical compound, the absorption spectrum of which is characterised by a band between Fraunhofer's lines C and D. The composition and properties of this compound, and the exact position in the spectrum of the band special to it, will be considered at some length further on. Suffice it to say here that the compound in question is obtained by the direct action of hydrogen sulphide on a solution of hæmoglobin or on diluted blood, and that the above-mentioned band is not a characteristic of the spectrum given by the blood of animals poisoned by the gas.

Although the direct action of hydrogen sulphide upon the blood-pigment has often been the subject of special inquiry, that of its analogues, hydrogen selenide and hydrogen telluride, does not seem to have claimed the attention of experimentalists. Eulenberg, who has experimented on animals with these two gases, makes no special mention of the spectrum of blood subjected, outside the body, to their action. Preyer, in his *Die Blutcrystalle*, 1871, does not allude to their direct action on the blood-pigment; and L. Hermann concludes a brief consideration of their toxic effects with the statement, "Die Wirkung beider gase auf Blut ist nicht untersucht."¹

Now, as is well known, the physical and chemical properties of hydrogen sulphide, hydrogen selenide, and hydrogen telluride are, in many respects, analogous. Thus for instance, they are colourless gases, they are soluble in water, and they possess a certain quality in their distinctive odours which is common to all three. Moreover, they are combustible, burning with a

¹ *Lehrbuch der experimentellen Toxikologie*, 1874, p. 131.

more or less bluish flame; their reaction is slightly acid; and they give precipitates, consisting of metallic sulphides, selenides, and tellurides, with the solutions of the salts of most metals.

The relationship between these gases being so very close, if the fact that hydrogen sulphide acts in a special manner on hæmoglobin be borne in mind, the idea that there might be some analogy between their mode of action on the blood-pigment will not seem far-fetched. This idea first occurred to Dr J. B. Haycraft, and it was at his suggestion that this research on the direct action of the three gases on the blood-pigment was undertaken.

Hydrogen sulphide, hydrogen selenide, and hydrogen telluride were brought in contact with diluted blood, that they might act on the oxyhæmoglobin, and the results of their direct action on the blood-pigment were carefully compared with one another, special attention being paid to the spectrum of the blood so treated.

Before going into the details of my experiments with these gases, I think it well to indicate, as briefly as possible, how each of them was prepared. I shall not dwell, at any length, on the apparatus used in their preparation, for they being such as ordinarily serve for the preparation of gases, a detailed description of them is uncalled for.

Hydrogen sulphide was attained by gently heating antimony trisulphide, in a flask, with strong hydrochloric acid. The gas evolved was passed through two wash-bottles containing water rendered alkaline by the addition of an aqueous solution of caustic potash. The gas, having been washed, was passed over dry fragments of caustic potash, contained in a U-shaped tube, after which it was collected over mercury, in small jars having a capacity of 50 c.c. and provided with ground glass stoppers. Each stopper was carefully greased, and inserted under mercury into its corresponding jar, this being filled with gas. A supply of hydrogen sulphide could thus be kept at hand to be used when necessary. Hydrogen sulphide prepared in this way was found, on analysis, to be purer than when obtained by the action of dilute hydrochloric or sulphuric acid on ferrous sulphide.

Hydrogen selenide was obtained by acting on freshly prepared sodium selenide, in a small flask, with dilute hydrochloric acid. After experimenting with the selenide of several metals, I elected to use that of sodium, prepared by fusing, in a porcelain crucible, pure metallic sodium with an excess of selenium reduced to a coarse powder. The combination takes place with the evolution of much heat and light, and to lessen the violence of the reaction, it was found necessary to prepare the compound in an atmosphere of nitrogen. The gas was washed in order to rid it of any trace of hydrochloric acid, which

might have passed over with it. This was rendered imperative by the fact that the presence of any hydrochloric acid in the gas used would have made the results obtained unreliable; but washing entailed a loss of part of the gas, for it is very soluble in water, and its solution soon absorbs oxygen and decomposes. Its solubility in water precluded its being collected over this liquid, even when this had a layer of oil on its surface; and the gas had consequently to be collected over mercury. On account of the readiness with which it attacks this metal, only a small quantity of the gas was prepared at a time, and that was used as soon as possible after being obtained.

Hydrogen telluride was prepared by acting on sodium telluride, in a flask, with dilute hydrochloric acid. I found that the gas, thus prepared, was purer than when obtained by the action of dilute hydrochloric acid on zinc telluride. The method of preparing and collecting this gas is identical with that adopted in the case of hydrogen selenide, and calls for no special description. I may, however, state that hydrogen telluride is more stable, in the presence of water, than hydrogen selenide, and keeps better over mercury.

I need hardly say that the greatest care was bestowed on the preparation of these gases. The preparation of hydrogen selenide and hydrogen telluride especially demanded much painstaking, and it was only after many trials that I succeeded in obtaining them in a sufficiently pure state.

Direct Action of Hydrogen Sulphide on the Blood-Pigment.
—I made a number of experiments in order to study the successive changes that take place in blood acted on by hydrogen sulphide. The blood used in most of them was fresh rabbit's blood. This was diluted with 100 volumes of water, then shaken and filtered. Experiments were also made with the blood of other mammals. Throughout this research, the blood used was always diluted to the same extent.

The method of experimenting first adopted consisted in passing a current of the gas through the diluted blood, small quantities of which were taken from time to time for spectroscopic examination. This method answered well enough for demonstrating the naked-eye appearances of blood so treated, but proved inadequate for enabling one to follow, with accuracy, the successive changes in its spectrum. I had, therefore, to devise another method, which enabled me to observe, to greater advantage, the changes in the spectrum of blood when brought in contact with hydrogen sulphide. This method consists in causing the gas to act upon diluted blood, in an absorption tube standing over mercury. Some of the pure gas is introduced into a non-

graduated absorption tube standing over mercury. The diluted blood is next introduced by means of a curved pipette, and the spectroscopic examination of the blood is forthwith proceeded with. While the observer is carefully watching the spectrum, the absorption tube is gently shaken from time to time, so as to bring different parts of the diluted blood into contact with the gas, and the changes in the spectrum are noted.

For all the experiments, care was taken that the tubes used were of a uniform calibre, with an internal diameter of 12 mm. The spectroscope used was a Browning chemical spectroscope, having cross wires in the telescope for centralising absorption bands. The slit was always kept of the same width.

I shall first describe the naked-eye changes, which occur in diluted blood treated with hydrogen sulphide, in the manner indicated above, and shall next consider the changes in the spectrum of blood so treated.

Naked-Eye Changes.—The diluted blood, which, to begin with, is of a bright red colour, gradually assumes a dark red hue. This soon changes to a greenish red, and eventually to an olive green. While these changes are in progress, the solution first becomes turbid, and then a dirty greenish brown precipitate, which soon settles on standing, is formed. This precipitate consists of sulphur and an albuminous substance. The olive green colour of diluted blood treated with hydrogen sulphide is permanent, and remains unaltered even after exposure for several days to the action of the air.

Changes in the Spectrum.—(a) The two bands of oxyhæmoglobin between Fraunhofer's lines D and E gradually become less distinct, while the interval between them becomes obscured. This dimming of the space between the two bands points to a commencing reduction of the oxyhæmoglobin. (b) An absorption band appears between the lines C and D. This band is discernible before the disappearance of the two bands of oxyhæmoglobin—a very interesting fact, showing that the compound, to which the band between C and D owes its presence, begins to be formed prior to the complete reduction of the oxyhæmoglobin. (c) As the band between C and D becomes more sharply defined, the bands of oxyhæmoglobin become fainter, and ultimately disappear. They are replaced by the

broad band of reduced hæmoglobin between D and E, the darkest part of which occupies the space formerly existing between the bands of oxyhæmoglobin. (d) On the further action of the gas, the band of reduced hæmoglobin disappears, leaving only the band between C and D. (e) This band ultimately vanishes, after the continuous action of the gas on the diluted blood, for several hours. It is worthy of notice that, while these changes are taking place, there is a gradual absorption of certain colours of the spectrum, viz., the violet, indigo, and blue, as well as the red end. The obscuring of these colours is concurrent with the changes in the colour of the diluted blood acted on by hydrogen sulphide. The reduction of the oxyhæmoglobin is effected in a very short space of time, in less time than when hydrogen or carbon dioxide is passed through diluted blood; but this apparently specific affinity of hydrogen sulphide for the oxygen of oxyhæmoglobin will not be deemed very remarkable, if one remembers that the gas is a powerful reducing agent.

Diluted blood treated with hydrogen sulphide, and showing the band between C and D, was kept in hermetically sealed tubes, and examined from time to time with the spectroscope. The band was found to persist for a period of time, varying from two to six months.

I ascertained the wave-length of this band, following the method recommended by MacMunn,¹ and found its central part to have a wave-length of $\cdot 000614$ millimetre. This figure represents an average of some fifty observations. On comparing the position of the absorption band in question with that of the band of acid hæmatin between C and D, I found that the acid hæmatin band lay nearer C. The central part of this band was

¹ MacMunn, *Spectroscope in Medicine*, 1880, pp. 31–33. A sheet of sectional paper, ruled in square inches and tenths is taken, and a scale of wave-lengths ruled off along the right-hand edge, and the scale of the spectroscope marked on the edge at right angles to the former. The value of the wave-length of each Fraunhofer line being known, and its value on the scale of the instrument having been ascertained, each line is marked in its proper position on the chart. The sites of the principal lines are then joined by a curve drawn through them. Knowing the reading of any absorption band on the scale of the spectroscope, and between which two Fraunhofer's lines it is situated, its position on the curve can be readily found. By referring to the right edge of the chart, its wave-length will be ascertained.

found to have a wave-length of $\cdot 000636$ millimetre. Nor did the band given by blood treated with hydrogen sulphide coincide with that of met-hæmoglobin, between C and D.

When discussing the probable composition of the compound to which the band between C and D, obtained when diluted blood is acted on directly by hydrogen sulphide, owes its presence, I shall have occasion to consider fully the views of observers on that point. Meanwhile, I will give a succinct account of the results obtained by the direct action of hydrogen selenide and hydrogen telluride on diluted blood.

Direct Action of Hydrogen Selenide on the Blood-Pigment.

As in the case of hydrogen sulphide, the hydrogen selenide was made to act, in an absorption tube standing over mercury, upon blood diluted with 100 volumes of water and filtered. The tube was gently but seldom shaken, while the diluted blood was being examined with the spectroscope; for the chemical action of hydrogen selenide is somewhat energetic, and it was essential, for purposes of observation, that its action on the blood-pigment should be exerted gradually.

Naked-Eye Changes.—The first change seen is a cloudiness of a reddish-brown hue, which begins at the junction of the diluted blood with the gas, and gradually pervades the whole solution. The diluted blood then presents a reddish-brown tint. The slight turbidity is soon followed by the formation of a dirty reddish-brown precipitate, which settles on standing. These changes occur very rapidly if the tube be much shaken, and a reddish-brown froth with reddish particles in it collects on the surface of the solution. These particles are probably particles of selenium derived from the partial oxidation of the gas, at the expense of the oxygen of the oxyhæmoglobin.

After the precipitate has settled, the supernatant liquid remains quite limpid. I have seen it almost colourless, when the diluted blood had been acted upon for some considerable time by the gas.

Changes in the Spectrum.—If the spectroscopic examination of the diluted blood be proceeded with immediately after the gas has come in contact with it, the following successive changes

in its spectrum are observed:—(a) A gradual dimming of the interval between the two bands of oxyhæmoglobin, while these at the same time become less intense. (b) Before the disappearance of these bands, there appears a third band between C and D. This band is at first very faint, but it soon becomes more evident and sharply defined. (c) The bands of oxyhæmoglobin eventually disappear, and only the single band of reduced hæmoglobin is observed between D and E. This band soon vanishes. Sometimes, the reduced hæmoglobin seems to decompose as soon as it is formed; for the only indication of there being reduced hæmoglobin in the solution, the dimming between the two bands of oxyhæmoglobin vanishes simultaneously with them. (d) The band between C and D ultimately disappears, after the prolonged action of the gas on the diluted blood. As in the use of diluted blood treated with hydrogen sulphide, there is a gradual absorption of the violet, indigo, and blue, as well as the red end of the spectrum.

Diluted blood treated with hydrogen selenide was kept in hermetically sealed tubes, and examined occasionally with the spectroscope. The band between C and D was found to persist no longer than from two to four days. It would, therefore, seem that the compound to which it is due is less stable than that obtained by the action of hydrogen sulphide on diluted blood.

The wave-length of the central part of the band special to blood treated with hydrogen selenide was measured and found to be $\cdot 000626$ millimetre. It is therefore obvious that it is nearer C than is the band given by blood treated with hydrogen sulphide. Moreover, the band does not coincide with that of acid hæmatin between C and D.

Direct Action of Hydrogen Telluride on the Blood-Pigment.

The method of experimenting was the same as that adopted for studying the action of hydrogen sulphide and that of hydrogen selenide on the blood pigment.

Naked-Eye Changes.—Almost immediately on introducing the diluted blood into the tube containing the gas, a cloudiness of a dark brown colour is observed in the part of the solution in contact with the gas. This cloudiness soon pervades the whole

solution, which becomes in a short time quite turbid. A precipitate is formed, which on settling is seen to be of a dirty dark brown colour, with blackish particles in it. These are probably particles of tellurium resulting from the partial oxidation of hydrogen telluride. The precipitate settles on standing, and then the supernatant liquid has a decidedly greenish-brown tint.

Changes in the Spectrum.—(a) The two bands of oxyhæmoglobin become less intense, while the interval between them gets dim, indicating a commencing reduction of the oxyhæmoglobin. (b) A third band appears between B and C, even before the disappearance of the two bands of oxyhæmoglobin. This band is nearer the red end of the spectrum than is either the band given by blood treated with hydrogen sulphide, or that special to blood acted on by hydrogen selenide. (c) The oxyhæmoglobin becomes entirely reduced, and only a single band is seen between D and E, in addition to the band in the red. (d) The band of reduced hæmoglobin next disappears, leaving only the band in the red of the spectrum. (e) This band, in its turn, vanishes after the prolonged action of the gas on the diluted blood. Besides these changes in the spectrum, the violet, indigo, and blue colours of the spectrum are powerfully absorbed, after the gas has been acting on the diluted blood for some minutes. There is also some absorption at the red end.

The band in the red, in this case, disappears quickly, and seldom persists more than two days, if blood treated with hydrogen telluride and showing this band in its spectrum, be kept in hermetically sealed tubes.

The wave-length of the central part of this band was determined, and found to be $\cdot 000665$ millimetre.

On comparing the results obtained with the three gases, it will be seen that there is a striking analogy between their mode of action on the blood-pigment. All these being powerful reducing agents reduce the oxyhæmoglobin more or less readily. But besides effecting this reduction, they exert a further action on the reduced hæmoglobin resulting in its decomposition and the formation of compounds each of which is characterised by an absorption band special to it. The fact that the band of reduced hæmoglobin gradually disappears, leaving only the characteristic band to the left of D, is, to my mind, a clear

evidence of this further action. The compounds formed are ultimately destroyed by the prolonged action of the gases, their destruction being marked by the disappearance from the spectrum of the band peculiar to each of them. I say compounds, for, as has been pointed out, there is a gradual shifting of the characteristic band towards the red end of the spectrum, according as the diluted blood is acted on by H_2S , H_2Se , and H_2Te . This shifting of the band would not take place, if the same identical compound were formed in each case.

Probable Composition of the Compounds formed by the Action of Hydrogen Sulphide, Hydrogen Selenide, and Hydrogen Telluride, on diluted Blood.

As regards the probable composition of the compound to which the band given by diluted blood treated with hydrogen sulphide owes its presence, I may refer to the views of several observers, who have experimented with this gas.

Eulenberg believes the compound to be of the nature sulph-methæmoglobin;¹ whereas Lankester calls it sulph-hæmoglobin.²

According to Kauffmann and Rosenthal, the compound is identical with hæmatin.³ "One sees near the band of reduced hæmoglobin the characteristic band of hæmatin. The latter is always more distinct than the former, and after some time only hæmatin remains, and there is no more hæmoglobin in the solution."

Hoppe-Seyler,⁴ while regarding the compound as being very similar to methæmoglobin, considers it to be a sulphur compound of hæmatin and hæmoglobin. This compound, he asserts, is decomposed by the prolonged action of hydrogen sulphide into sulphur, an albuminous substance, and a third compound to which the olive green colour of blood so treated is due, and which contains all the iron of the hæmoglobin.

In the face of such diversity of opinion on the nature of the compound, it is well, I think, to sift the subject out, and, by giving reasons for or against the adoption of any particular view, to try to arrive at some conclusion as to the composition of the compound in question.

¹ Dragenorff, *Manuel de Toxicologie*, trans. by Gautier, 1886, p. 107.

² Lankester, *Jour. Anat. and Phys.*, iv., 1870, pp. 124 and 125.

³ *Archiv für Anat. und Physiol.*, 1865, p. 660.

⁴ *Zeitsch. für Physiol. Chemie*, i., 1877, p. 134; *Med. Chem. Unter.*, i. p. 299.

And, first, is the compound methæmoglobin, or a combination of methæmoglobin with hydrogen sulphide?—Although the compound resembles methæmoglobin in powerfully absorbing violet and blue light, it differs from methæmoglobin in this, that its characteristic band in the spectrum does not coincide with the band of the latter compound between C and D. Moreover, the compound is not reduced on the addition of ammonia and ammonium sulphide, whereas methæmoglobin is. And, indeed, if one remembers that hydrogen sulphide is a powerful reducing agent, and that methæmoglobin is obtained by the action of oxidising agents on oxyhæmoglobin or reduced hæmoglobin, one will not fail to perceive that there is little likelihood of the compound being methæmoglobin. The formation of methæmoglobin in this instance is, to my mind, in the highest degree improbable. Nor is there any evidence in favour of the compound being a combination of methæmoglobin with hydrogen sulphide.

Is it a compound of hydrogen sulphide with hæmoglobin?—It is well known that several gases combine with hæmoglobin to form compounds which are more or less stable. For instance, carbon monoxide (CO) and nitric oxide (NO) form with hæmoglobin comparatively stable compounds, capable of resisting the action of reducing agents; while oxygen combines with it to form a more easily decomposable one. These compounds are crystalline, they are isomorphous, and they give two absorption bands in the spectrum between the lines D and E. These two bands, it is true, undergo a slight shifting in the case of carbonic oxide-hæmoglobin, and they are less intense than those of oxyhæmoglobin in the case of nitric oxide-hæmoglobin; but the fact remains that, for the three compounds above mentioned, the general form of spectrum remains the same—two absorption bands between D and E; and this is true not only of the compounds I have instanced, but also of other combinations of hæmoglobin with such gases as acetylene and cyanogen. Now, what happens when diluted blood is acted on by hydrogen sulphide? It is needless for me to repeat in detail what I have fully stated elsewhere. Suffice it to say that there is spectroscopic evidence to show that a gradual reduction of the oxyhæmoglobin occurs, followed by a decomposition of the reduced hæmoglobin. The

only absorption band that is characteristic of the direct action of hydrogen sulphide on blood, is the band between C and D. When diluted blood treated with hydrogen sulphide, and giving only this band, is exposed to the action of air, or to that of oxygen, in a tube standing over mercury, the band eventually disappears, but, as I have found, neither the bands of oxyhæmoglobin, nor that of reduced hæmoglobin reappears. The spectroscope then reveals the fact that, as a result of the direct action of hydrogen sulphide on diluted blood, hæmoglobin disappears altogether from the solution, and that a new compound is formed, which gives a band between C and D. This compound differs from several known compounds of hæmoglobin with gases, in having a form of spectrum different from theirs. Moreover, neither putrefaction nor prolonged contact with air or oxygen can dissociate it into hæmoglobin and hydrogen sulphide or sulphur. Now, even the stable CO-Hb is decomposed by prolonged contact with oxygen (Gamgee, Zuntz). There is, therefore, some evidence against the compound being Hb-H₂S; whereas not a single plausible argument in favour of its being the latter compound can be adduced.¹

Is the compound identical with hæmatin?—Hæmoglobin is, as a rule, decomposed into hæmatin and a colourless proteid closely related to globulin, by the addition of acids. Strong acids decompose it readily; weak acids more gradually. Hydrocyanic acid, indeed, forms an exception, for it combines with hæmoglobin to form a crystalline compound, giving a spectrum different from that of hæmatin. Now, the reaction of hydrogen sulphide is slightly acid; and, when diluted blood is treated with the gas, its reaction becomes slightly acid, and a precipitate is formed, which consists of an albuminous substance and sulphur. This being so, it seems, at first sight, quite natural to suppose, with Kaufmann and Rosenthal, that the band between C and D is due to hæmatin. But Hoppe-Seyler has shown

¹ I am not aware that there is a precedent of a compound of hæmoglobin with a gas, a compound with properties as well established as those of CO-Hb or NO-Hb, giving an absorption band between C and D. It is true that methæmoglobin, which has one of its bands between C and D, is regarded by some as a peroxidised hæmoglobin, a view to which Hoppe-Seyler is opposed. It contains more O than Hb-O₂, but the extra oxygen is combined with the iron of the latter compound (*Henninger*).

that the compound differs from hæmatin in this, that it is not reduced by the addition of ammonia and ammonium sulphide. The bands of reduced hæmatin do not appear in the green of the spectrum. Moreover, as has been pointed out, its characteristic band does not coincide with that of acid hæmatin between C and D.¹ But for these indications to the contrary, one would be inclined to say that the compound was hæmatin; for hydrogen sulphide acts after the manner of a weak acid.

*There is some evidence against the compound being hæmatin; but since the formation of hæmatin is possible, may it not be that hydrogen sulphide combines with hæmatin, as soon as this is formed, to form a new compound?—*It is well known that the crystalline compound hæmin is a chloride of hæmatin. In this compound the hæmatin is combined with two molecules of hydrochloric acid ($\text{Hæmatin} + 2 \text{HCl}$).

Again, if ammonia gas be passed for a considerable time through diluted blood, a band appears between C and D.² Now, caustic alkalies determine the decomposition of hæmoglobin into hæmatin and a substance related to globulin; and, no doubt, the ammonia gas acts in this way. But there appears to be a combination of the excess of ammonia with the hæmatin formed. Nay, the compound seems to be fairly stable, for it is only by heating it above 130°C . that the ammonia can be expelled.³ There is, therefore, a strong probability that the band between C and D is due, in this instance, to a compound of hæmatin with ammonia. The property of hæmatin to combine with HCl and, as seems probable, with NH_3 , inclines one to admit the probability of the compound obtained by the action of H_2S on blood being a combination of hæmatin with this gas. While not quite committing myself to the view that the band between C and D is due to a compound of hæmatin with H_2S , I am disposed to regard the formation of such a compound as being very probable.

For reasons similar to those given in the case of hydrogen

¹ Hæmatin in acid solution gives four bands, the most intense of which is between C and D.

² *Bull. de la Soc. Chem.*, 1868, p. 210. According to Koschlakoff and Bogomoloff, NH_3 appears to destroy hæmoglobin- O_2 without reducing it and without the formation of hæmatin. This statement lacks confirmation.

³ Gautier, *Chimie appliquée à la Médecine*, 1875, p. 479.

sulphide, it is not likely that the compounds obtained when diluted blood is treated with hydrogen selenide and hydrogen telluride are combinations of these gases with hæmoglobin or methæmoglobin. Nor are they hæmatin, although blood acted on by both gases has a slightly acid reaction. One cannot, however, but allow that hæmatin may combine with the two gases to form compounds.

Whatever be the real nature of the compounds obtained when diluted blood is treated with the three gases, the fact remains that the same general form of spectrum persists for them all—a single band to the left of D. It is also worthy of notice that the characteristic band shifts towards the red end of the spectrum, as the molecular weights of the compounds increase. So that the band of the compound with the highest molecular weight, the compound formed by H_2Te , lies nearest the red end; the band of the compound with the lowest molecular weight, that formed by H_2S , is furthest from the red end; and the band of the compound formed by H_2Se holds an intermediate position in the spectrum. This I consider to be a striking example of the relationship between the spectroscopic appearances and the chemical composition of substances which may be said to be of the same chemical group.

Is the band to the left of D characteristic of blood acted on directly by H_2S , H_2Se , or H_2Te , of any medico-legal importance?
—Although there can be no doubt about hydrogen selenide and hydrogen telluride being extremely poisonous, more so indeed than hydrogen sulphide, yet poisoning by them is not likely to occur except among persons engaged in preparing them. It is otherwise, however, in the case of hydrogen sulphide. Accidental poisoning by this gas does sometimes occur among men engaged in the cleaning of drains and sewers. It is, therefore, chiefly in reference to hydrogen sulphide that I set myself to answer the above question. Experiments were also made with hydrogen selenide and hydrogen telluride to compare their action on the blood with that of hydrogen sulphide when inhaled by animals.

The method of experimenting consisted in poisoning rabbits and guinea-pigs with either of the three gases, and examining their blood with the spectroscope, as soon as possible after death.

It is scarcely necessary to give here the symptoms of poisoning by hydrogen sulphide. They are fully discussed in works on Toxicology. Nor need the symptoms caused by hydrogen selenide and hydrogen telluride detain me long. Suffice it to say that in poisoning by hydrogen selenide there is every indication of considerable irritation, *e.g.*, lacrymation, discharge of mucus from the nose, sneezing, followed by dyspnoea, convulsions and death. The symptoms due to hydrogen telluride are, in the main, similar to those caused by hydrogen selenide, except that irritation of mucous membranes is much less marked. On *post-mortem* examination a reddish deposit is found on the mucous membrane of the nose, trachea, and bronchi of animals poisoned by hydrogen selenide, and a blackish deposit in the case of animals poisoned by hydrogen telluride. The deposit was especially noticeable in cases of poisoning by the former gas.

The blood of rabbits and guinea-pigs poisoned by either of the three gases is in every case darker than normal. On spectroscopic examination, the two absorption bands of oxyhæmoglobin were invariably seen, but the interval between them was markedly dimmed. Never was an absorption band seen to the left of D, either between C and D or between B and C. From this fact I infer that hydrogen sulphide, hydrogen selenide, and hydrogen telluride, when inhaled, effect only a partial reduction of the oxyhæmoglobin of the blood, and that their further action on the blood-pigment, resulting in its decomposition and the formation of new compounds, does not take place, the animals dying before the oxyhæmoglobin is completely reduced.

The single absorption band characteristic of blood treated outside the body with hydrogen sulphide, hydrogen selenide, and hydrogen telluride, is of no medico-legal value, inasmuch as in poisoning by those gases, death supervenes before they have had time to exert their special action on the blood-pigment.

MONTREAL, 13th July 1891.

SECOND ANNUAL REPORT OF THE COMMITTEE
OF COLLECTIVE INVESTIGATION OF THE ANA-
TOMICAL SOCIETY OF GREAT BRITAIN AND
IRELAND FOR THE YEAR 1890-91.¹ Reported by
ARTHUR THOMSON, M.A., M.B., *Lecturer on Anatomy,
University of Oxford.*

THE following questions were issued by the Committee of Collective Investigation of the Anatomical Society early in October 1890:—

1. Mode of origin of the following vessels, usually described as branches of the thyroid axis, viz., inferior thyroid, suprascapular, ascending cervical, and transverse cervical arteries.
2. Mode of distribution of the last dorsal and first lumbar nerves.
3. To note in each subject the distance of the lower margin of the kidney on each side from the iliac crest. The sex of the subject to be stated, and any naked-eye evidence of disease of the organs to be recorded.
4. The distribution of the cutaneous nerves on the dorsum of the foot and toes.
5. To note the occurrence of a diverticulum ilei (Meckel's), in each case giving details of its position and connections. It is particularly requested that the number of subjects examined be recorded, whether the diverticulum be present or no.

The returns have been most gratifying in point of numbers, and are a decided improvement on last year's Report. Twenty of the thirty-nine institutions to which notices were sent have participated in the scheme and have returned answers to some, if not to all, the questions. The Universities and the larger provincial schools are now well represented, and as the material at their command is extensive, their co-operation greatly enhances the value of the report.

¹ The First Report appeared in the *Journal of Anatomy and Physiology*, October 1890.

In three instances schools which sent in returns last year have taken no share in the present report.

Subjoined is a list of the schools to which notices were sent. An asterisk is placed opposite those from which returns have been received :—

St Bartholomew's Hospital, London.	*University of Durham School of Medicine, Newcastle-on-Tyne.
*Charing Cross Hospital, London.	*University of Edinburgh.
*St George's Hospital, London.	School of Medicine, Royal College of Surgeons, Edinburgh.
Guy's Hospital, London.	*School of Medicine, Minto House, Edinburgh.
King's College, London.	University College, Dundee.
London Hospital, London.	School of Medicine for Women, Edinburgh.
*St Mary's Hospital, London.	*University of Aberdeen.
*Middlesex Hospital, London.	*University of Glasgow.
St Thomas' Hospital, London.	Anderson College, Glasgow.
*University College, London.	St Mungo's College, Glasgow.
*Westminster Hospital, London.	Western Medical School, Glasgow.
*London School of Medicine for Women.	*School of Physic, Trinity College, Dublin.
Cook's School of Anatomy.	Carmichael School of Medicine, Dublin.
*University of Oxford.	*Catholic University School of Medicine, Dublin.
University of Cambridge.	Royal College of Surgeons, Ireland.
*Queen's College, Birmingham.	Queen's College, Belfast.
*Bristol Medical School.	Queen's College, Cork.
*School of Medicine, Yorkshire College, Leeds.	Queen's College, Galway.
*School of Medicine, University College, Liverpool.	
*The Owens College, Manchester.	
Medical School, Firth College, Sheffield.	

REPORT.

QUESTION I.

A large number of replies to the question on the branches of the thyroid axis have been sent in, and the Committee heartily thank the following gentlemen for their assistance :—

Messrs James Musgrove, University of Edinburgh ; Gordon Brodie, Middlesex Hospital, London ; C. Devereux Marshall, University College, London ; J. J. Long, Trinity College, Dublin ; P. R. W. Santi, School of Medicine, Newcastle-on-Tyne ; J. Symington, Minto House, Edinburgh ; W. Thelwall Thomas, University College, Liverpool ; J. A. H. White, Queen's College, Birmingham ; Edward Fawcett, Yorkshire College, Leeds ; — — —, St Mary's Hospital, London ;

78 REPORT OF COMMITTEE OF COLLECTIVE INVESTIGATION OF

A. Robinson and J. B. Carter, The Owens College, Manchester ; James Black, Westminster Hospital, London ; Hugh Sutherland, University of Aberdeen ; P. Brady and J. Dunne, Catholic University School of Medicine, Dublin ; A. Thomson, University of Oxford ; Misses Piercy and Bate, London School of Medicine for Women.

It has been found somewhat difficult to summarise the results obtained. It was felt that minute descriptions of the various anomalies met with would convey but a poor impression of the arrangement of the various vessels ; on the whole, it appeared best to tabulate the results in a graphic manner (see Tables I. and II.). In Table I., we have the nine most common modes of arrangement, placed in order according to their frequency. The figures on the table indicate the number of cases recorded out of a total of 544, and subjoined is also the percentage of occurrence of each type, the types being lettered A, B, C, &c., for convenience of reference ; where types are more or less allied, then the figures are lettered thus—P¹, P², P³ (Table II.).

In Table II. we have twenty-seven modes of arrangement figured ; as they are not so frequently met with, they have been printed off on a reduced scale. The numbers of their occurrence out of the total of 544 cases examined only has been given. The percentage of frequency has been omitted.

It may be said here that an effort has been made to restrict as far as possible the number of types, and the slighter variations have been, when possible, included under what may be termed the more common type. Again, latitude has been allowed in reference to the exact points of origin of the aberrant arteries, *i.e.*, whether they arise from the II. or III. parts of the subclavian. On the whole, however, the tables will be found to represent fairly accurately the numerous variations observed in the course of this investigation.

The various arteries are lettered as follows :—Inferior thyroid, I.T. ; ascending cervical, A.C. ; transverse cervical, T.C. ; suprascapular, S.S. ; superficial cervical, S.C. ; posterior scapular, P.S. ; internal mammary, I.M. ; vertebral, V.

As far as possible only those branches of the subclavian which are usually offsets of the thyroid axis are represented in the figure, as the enumeration of other details might tend to obscure the results desired. As to the relative frequency of variations on the right and left sides of the neck, the results obtained are not such as to enable us to draw any definite conclusions ; indeed, there appears to be no greater tendency for the occurrence of these varieties on one side more than the other.

Dr Robinson, of The Owens College, Manchester, describes a case in which the posterior scapular artery arose as a branch from the superior intercostal, and Mr P. Brady and Mr J. Dunne record a case, in the report from the Catholic University Medical School, Dublin, wherein the inferior thyroid, which was a branch of the thyroid axis, was double, the two trunks embracing the common carotid artery.

No attempt has been made to classify the different arteries according to the sources from which they arise. Should this be desirable, the means for doing so are readily accessible in Tables I. and II.

TABLE I.—Variations in the Branches of the Thyroid Axis. Total number examined 544.

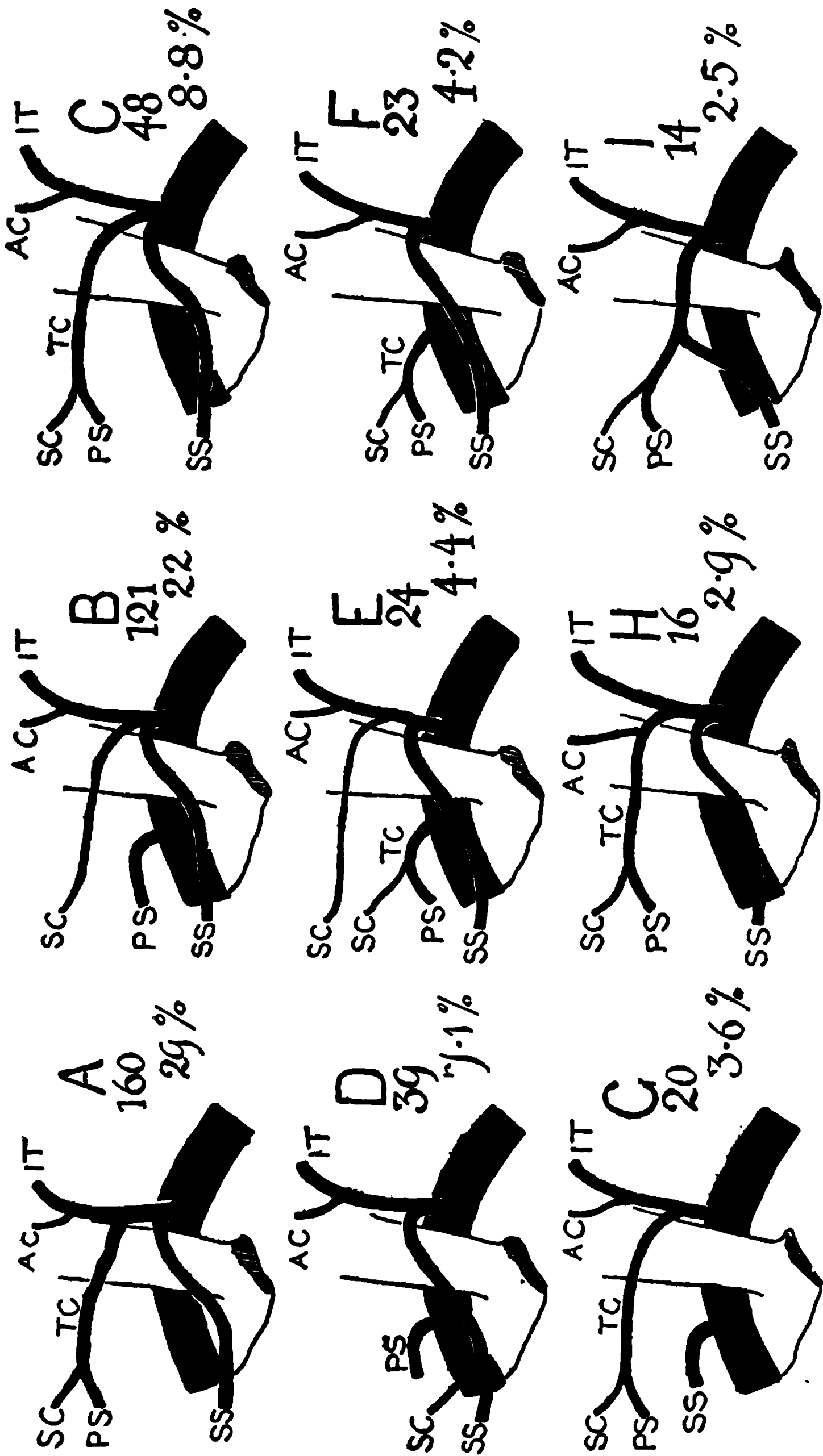
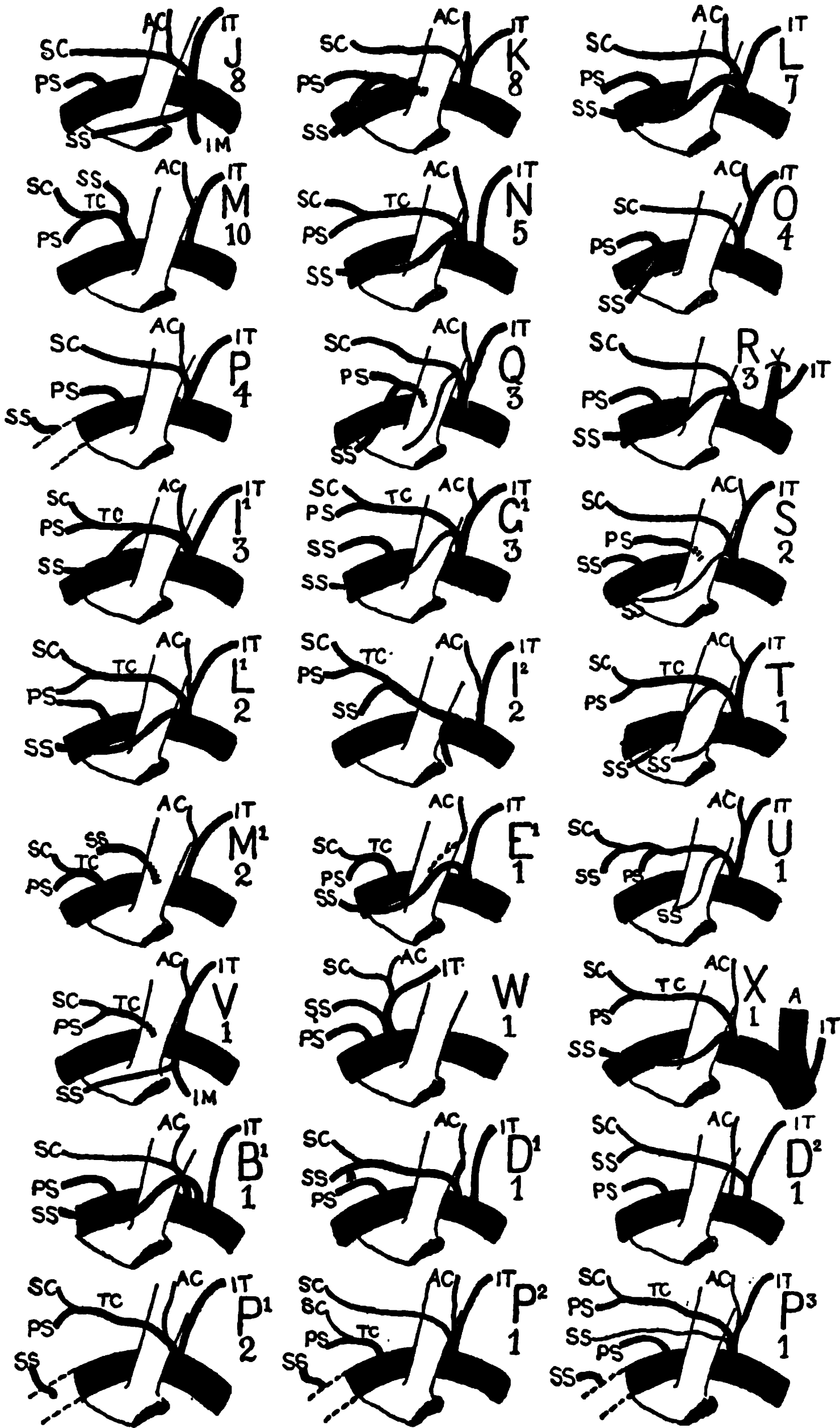


TABLE II.—*Variations in the Branches of the Thyroid Axis.*
Total number examined 544.



QUESTION II.

The replies to this question, on the distribution of the last dorsal and first lumbar nerves, are few in number. This is readily explained, for to have answered fully would have necessitated a very careful supervision of the dissections at various stages, and several teachers have written to the secretary regretting that they have had to abandon the investigation owing to the uncertain and unsatisfactory nature of the results obtained by their assistants.

The following sent in reports:—Messrs Montague Griffin, Trinity College, Dublin; Walter Chapman, Queen's College, Birmingham; Gordon Brodie, Middlesex Hospital, London. The Misses Piercy and Bale, London School of Medicine for Women.

In arranging the facts observed, the variations only are noticed in the following summary, accepting as normal that arrangement which is described in the standard English text-books.

Eighty-three subjects have been examined, and details thought worthy of note by the various observers are enumerated in the sub-joined report.

Mr MONTAGUE GRIFFIN in this connection sends an interesting note in regard to the nerve supply of the pyramidalis:—"I have been able," writes he, "to verify the nerve supply of this muscle in only seven cases. In others, where the nerve had been found, previous dissection had destroyed its connections. When found it was always by the adoption of one method. The sheath of the muscle was opened, the apex detached from the linea alba, and the muscle reflected downwards, carefully looking for any filament of nerve entering its posterior surface. The first nerve which was seen entering its posterior surface was proved, on tracing it outward, to arise on each side from the ilio-hypogastric; it passed inwards on both sides beneath the pillars of the ring. The remaining six nerves observed supplying the muscle came from the last dorsal nerve. The nerve pierces the substance of the rectus muscle about the middle of the posterior surface of the pyramidalis. The last nerve supply which I found would, I thought, have verified the condition which Ellis describes as the normal. A nerve filament passed up out of the inguinal canal, seemingly from the ilio-inguinal nerve, and passing beneath the pillars of the ring entered the posterior surface of the muscle. However, further examination of this subject proved that this was the case where the last dorsal nerve played the part of the ilio-inguinal—it would seem as if, having gone on another man's errand in supplying the inguinal region, it recollected itself and sent back a twig to perform what *seems* to be one of its normal duties—the nerve supply of the pyramidalis."

Summary of Variations met with in the Origin and Distribution of the Last Dorsal and First Lumbar Nerves.

XII. DORSAL NERVE

division absent in one case—replaced by a branch from I. lumbar, which likewise furnishes and ilio-inguinal.

Do. *Iliac branch absent in five cases—replaced by iliac branch of ilio-hypogastric.*

DORSAL-LUMBAR NERVE present in five out of 6 subjects examined.

COMMUNICATING BRANCHES between XII. Dorsal and I. Lumbar nerves in the abdominal wall present in two out of seven subjects examined (Queen's College, Birmingham) and in many (number not stated) cases from Trinity College, Dublin.

I. LUMBAR NERVE—

ial, which in both cases took a course similar to the external
e case its distribution was normal, in the other instance it furnished

iliac branch of XII. dorsal.

; branch of ilio-hypogastric pierced the internal oblique immediately
ween the internal and external oblique muscles previous to piercing
ications with the XII. dorsal. In the gluteal region it formed a
network of communications with the external cutaneous branches of the posterior primary divisions of the lumbar
cases supplied the region of the tensor fasciae femoris muscle by means of a special branch.

reach) usually became cutaneous 2 to 2½ inches above level of the pubis; in one case it appeared

ilio-inguinal in 9 subjects arose by a conjoint trunk.

n one case from II. lumbar nerve.

in two cases. In one replaced by XII. dorsal, in the other by genital branch of genito-crural.

Do. reciprocal in point of development with ilio-hypogastric.

MUSCULAR NERVES—

Muscular branches were noticed in one case coming off from the ilio-hypogastric and ilio-inguinal to supply the muscles of the
abdominal wall.

A muscular branch in one case arose from the

The psoas parvus was observed in one case to 4

The nerve to the *Pyramidalis*, with the above

which, after piercing the rectus muscle

the XII. dorsal nerve took the place

abdominal ring to reach the deep surface

Total number of subjects examined, eighty-three.

r the *pyramidalis* muscle.

to spring from the XII. dorsal nerve,
at its middle. In one case, in which
id the internal pillar of the external

QUESTION. III.

The following observers have furnished records of the distance of the kidneys from the iliac crest:—

Messrs J. H. M'Gee, Catholic University Medical School, Dublin; P. Macleod Yearsley, Westminster Hospital; ———, St Mary's Hospital; F. H. Marston, Queen's College, Birmingham; J. H. Teacher, University of Glasgow; Gordon Brodie, Middlesex Hospital; Edward Fawcett, Yorkshire College, Leeds; James Musgrove, University of Edinburgh; A. Robinson, Owens College, Manchester; W. H. Thomson, Trinity College, Dublin; A. H. Walker, Charing Cross Hospital; A. Thomson, University of Oxford.

Here again an effort has been made to combine the advantages of a numerical and graphic method; Tables III. and IV. show, placed side by side, the results obtained by such an arrangement of the measurements in the males and females respectively. The central column in each figure represents in inches and corresponding millimetres the distance above and below the iliac crest. On either side is arranged in black blocks, drawn to scale, the number of cases which have been noted in which the lower border of the organ corresponds to the level shown on the scale above or below the iliac crest.

A glance at the chart will prove how misleading an average may be, and for this reason no attempt has been made to summarise the results. A curve uniting the extremes of the black blocks will more correctly express the facts. The somewhat striking differences to be noted between the number of cases recorded at, say 1 inch above the iliac crest and those at $1\frac{1}{2}$ inch, is readily explained by reason of the tendency to avoid small fractions of an inch; if, therefore, we would disregard all measurements below $\frac{1}{4}$ of an inch, we are likely to get results more generally uniform, and yet sufficiently accurate for all purposes.

In the males in one case, where both kidneys lay on a level with the iliac crest, the liver was much enlarged. In another case, where the kidneys lay at or about this level, they still retained their foetal segmentation. Two cases were noted as cirrhotic, which lay about 1 and 2 inches respectively above the crest; and one case, where the left kidney lay $2\frac{1}{4}$ inches above the crest, the organ was remarkable for its very small size.

Among the females, a subject was examined in which the kidneys could be moved,—the right from a point $\frac{3}{4}$ of an inch below the crest to a point $\frac{3}{4}$ of an inch above the crest, the left from a point 1 inch below the crest to a point $1\frac{1}{4}$ inch above the crest. In another subject, in which the spinal column was curved laterally to the right in the lumbar region, the right kidney lay $\frac{3}{4}$ of an inch below the iliac crest. In a case where the left kidney lay $1\frac{1}{4}$ inch below the iliac crest the organ itself was enlarged, as also was the spleen; the gall-bladder, too, was much distended. In another case in which

TABLE III.—*Males.*

h. m.

1

2

1

4

12

4

4

19

19

8

6

4

11

4

9

2

8

4

7

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

34

Note.—Through error these diagrams have not been reduced to an inch scale as was intended.

TABLE IV.—*Females.*

RIGHT	In. mm (S. 1961)	LEFT
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the left kidney lay on a level with the iliac crest, a much-enlarged spleen was noticed. This was also the case in a subject in which the left kidney lay $1\frac{1}{2}$ inch above the crest. In three cases, where the kidneys lay at or near the level of the crest, the organs were noted as enlarged and fatty.

Dr W. H. THOMSON, of Trinity College, Dublin, appends the following note to his report:—

“The kidneys of the female were found to be on a lower level than those of the male. This is not only indicated by the average, but it becomes more clearly shown when the individual cases are examined. Thus, eight of the twenty-seven female kidneys on the right side and five on the left were either as low as, or lower than the crest, while only two of the right male kidneys and none of the left were in contact even.

“This suggested the influence of tight lacing in some at least of the female subjects. In one female subject, in which there was much evidence of extreme tight lacing (other than that indicated by kidney level), it was found that the kidney was very high up above the iliac crest, in fact completely hidden by the liver, which was apparently displaced downwards. Moreover, the organ was very small, that is, apparently atrophied from the pressure which the liver exerted upon it.”

The same observer notes the average distance of the centre of the curve of the lower border of the kidney from the mid-dorsal line as 7.25 cm. on the right side in males and 7 cm. on the left. This latter distance was also found to be the average on both sides in the female subject.

Mr J. H. TEACHER, of the University of Glasgow, in discussing the differences between the male and female measurements, says—“The difference in the level of the kidneys in the male and in the female subjects seems to be nearly in proportion to the difference in height. But whereas in the female the kidneys were abnormally low from being loose and from depression of the organs, especially the liver, there was only the case of hydronephrosis in which, in the male, the kidney was below the level of the crest of the ilium. In one or two cases in females, where there was great depression of the lower ribs and abdomen, the liver and spleen were depressed upwards; but, as the liver was turned a little so as to be deeper than normal, it is at least doubtful whether the kidney could be drawn up or not.”

Measurements have been taken in 448 cases—264 in males, 184 in females. In males the largest number of kidneys on the right side lie between $\frac{3}{4}$ of an inch and $1\frac{1}{2}$ inch above the iliac crest; on the left side between 1 and 2 inches above the crest. Twenty-four kidneys lie at or below the level of the iliac crest out of a total of 264.

In the females forty-eight kidneys lie between $\frac{3}{4}$ of an inch and $1\frac{3}{8}$ inch above the level of the iliac crest on the right side—forty-one between $1\frac{1}{4}$ and $1\frac{5}{8}$ inch above the level of the iliac crest on the left side. Twenty-nine kidneys out of a total of 184 lie either at or

below the level of the iliac crest; or, expressed in other words, 15 per cent. of kidneys in the female are placed either on or below the level of the iliac crest as compared to 9 per cent. in the males.

Dr HERBERT R. SPENCER has forwarded from University College, London, a series of measurements regarding the position of the kidneys in the infant at birth. His report is printed in its entirety.

THE DISTANCE OF THE LOWER MARGIN OF THE KIDNEY FROM THE ILLIAC CREST IN THE INFANT AT BIRTH. By HERBERT R. SPENCER, M.D., B.S., M.R.C.P.

The accompanying table is a record of observations on forty human foetuses which were either still-born or lived only a few hours. Fourteen of them had undergone intra-uterine maceration. The foetus having been laid supine, with extended lower limbs, the abdomen was opened by a longitudinal median incision, and the kidneys exposed by dividing the rectum and turning it and the descending colon and the cæcum and ascending colon up for a sufficient distance. The small intestines were then held out of the way, and the peritoneum and areolar tissue around the kidney divided so as to clearly define the lower end of the organ. The measurements were taken from the tip of the anterior superior iliac spine to the level of the lower margin of the kidney on each side. The iliac spine was chosen in preference to the top of the crest, owing to the difficulty of accurately measuring the small distance between the top of the crest and the kidney in the new-born child, without greatly disturbing the natural relations, to avoid which, also, the thoracic organs and liver were left *in situ*.

From the table it appears that the right kidney was nearer to the level of the right anterior superior iliac spine than was the left to its corresponding spine in all except nine cases; in three of these it was further removed by $\frac{1}{8}$ of an inch; in the other six it was at the same distance. In two of these six cases (20, 24), however, my notes state that, although the distances were equal, the lower end of the right kidney was situated at a lower level than the left, with reference to a line drawn at right angles to the sagittal plane bisecting the vertebral column. In the cases in which the distance between the anterior superior iliac spine and the kidney was less on the right side, this kidney was also anatomically the lower.

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There was no naked-eye disease of the organs which could affect the measurements, the morbid appearances being limited to minute hæmorrhages into the substances of and around the kidney.

No.	Sex.	Length (in inches).	Weight.		Height (in inches) of Right Kidney above Anterior Superior Iliac Spine.	Height (in inches) of Left Kidney above Anterior Superior Iliac Spine.	Remarks.
1	M.	20½	lb.	oz.			
2	F.	17½	8	12	1½	1½	Macerated.
3	M.	20½	5	18	Right kidney than	ney ⅛ lower left.	
4	M.	18	4	7	1 ½	1½ ½	Macerated. Left diaphragmatic hernia.
5	M.	12½	1	7½	½	½	
6	F.	18½	4	4	1 ½	1½ ⅛	Macerated.
7	M.	18	1	9	½	1½ ⅛	
8	F.	16	8	8	½	½	Macerated.
9	F.	16½	4	10	½	1	Macerated.
10	F.	11	1	7	½	½	
11	F.	14	1	11½	½	½	Macerated.
12	M.	20	7	0	1½ ⅛	1½	
13	F.	20½	7	8	1½	1½	
14	F.	18½	5	9½	1½ ⅛	1½ ⅛	
15	F.	18	1	4	⅞	⅞	
16	F.	18½	5	8	½	½	Enormous liver and spleen.
17	M.	20½	6	7	1½ ⅛	1½	
18	M.	18½	4	8	(½ above crest of ilium).	(½ above crest of ilium).	} Twins.
19	M.	20	5	6	½	1½	
20	M.	19	6	8½	1½ ⅛	1½ ⅛	
21	M.	18	4	8½	½	1½ ⅛	Macerated.
22	F.	18	4	8	1	1	Macerated.
23	F.	22	8	6	1	1½	Macerated.
24	F.	17	3	12½	1½ ⅛	1½ ⅛	
25	M.	19	5	11	1½	1½	
26	F.	12	1	2½	½	½	Macerated.
27	M.	18½	5	6½	1	1½	Macerated.
28	M.	20	4	8	⅞	½	Macerated.
29	F.	19	5	4	½	½	
30	M.	12½	1	13	½	½	
31	M.	15	2	7½	½	½	
32	M.	18½	4	13	½	1	
33	M.	20	5	11½ (without brain).	1½	1½	
34	M.	14	1	12	⅞	½	Macerated.
35	M.	18½	5	8	1½	1½	Macerated.
36	F.	17½	3	9	⅞	1½ ⅛	
37	M.	20	6	6	½	⅞	
38	F.	15½	2	7½	1½ ⅛	1½ ⅛	
39	F.	15½	2	8	½	½	} Triplets.
40	F.	15½	2	6½	½	½	

QUESTION IV.

A comparatively small number of observations has been made on the distribution of the cutaneous nerves to the dorsum of the foot. Returns have been received from the following:—

Messrs Gordon Brodie, Middlesex Hospital; E. H. Shaw, University College; ————, St Mary's Hospital; P. Macleod Yearsley, Westminster Hospital; W. A. Harris, Queen's College, Birmingham; E. Fawcett, Yorks College, Leeds; J. W. Smith and J. B. Carter, The Owens College, Manchester; P. R. W. Santi, School of Medicine, Newcastle-on-Tyne; J. Symington, Minto House, Edinburgh; H. L. Sutherland, University of Aberdeen; A. F. Dixon, Trinity College, Dublin; A. Blaney, Catholic University Medical School, Dublin; A. Thomson, University of Oxford. Misses Piercy and Bale, London School of Medicine for Women.

A total of 229 feet have been examined, and in tabulating the results the graphic method has been adopted in preference to the descriptive. Twelve types are figured, and lettered A, B, C, &c., in order of their frequency. The first six are arranged in such a way as to show how the external saphenous replaces the external division of the musculo-cutaneous nerve, or *vice versa*. The last six (H, K, I, F, G, E) are arranged to display the progressive variations in the cutaneous distribution of the anterior tibial nerve.

In these types connecting loops between the nerves have been in some cases omitted, as the information necessary was not sufficiently complete.

The figures attached to the types indicate the numbers of such specimens out of the total of 229 examined. In some cases the percentage is also given.

The musculo-cutaneous is represented by a solid black line; the external saphenous by a dotted line. The anterior tibial by a double outline.

The so-called normal arrangement represented by type A occurs in 55 per cent. of cases. Next in order is type B, where the external saphenous supplies the two and a half outer toes. This distribution of the nerves was met with in 24 per cent. of the feet examined. For further details the reader is referred to Table V.

In one case, recorded by Mr J. W. Smith of The Owens College, the internal saphenous supplied the inner side of the great toe; in another, it reached the inner side of the head of the metatarsal bone.

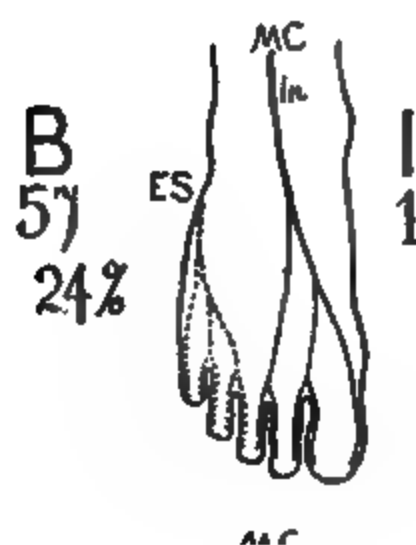
[TABLE V.

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TABLE V.—*Variations in the Distribution of the Cutaneous Nerves on the Dorsum of the Foot. Number of Feet examined, 229.*

ES	L 3	A 127 55%	D 4
----	--------	-----------------	--------

E	C 19 8%	E
---	---------------	---



E	H 1	K 1	J 4
---	--------	--------	--------

F 6	E	G 3	E 3
--------	---	--------	--------

QUESTION V.

In answer to the question, as to the occurrence of the diverticulum ilei, replies have been received from—

Messrs H. Hunter, Trinity College, Dublin; A. Robinson, Owens College, Manchester; ———, St Mary's Hospital, London; F. H. Marson, Queen's College, Birmingham; Gordon Brodie, Middlesex Hospital, London; H. L. Sutherland, University of Aberdeen; W. Thelwall Thomas, University College, Liverpool; P. Macleod Yearsley, Westminster Hospital; P. R. W. Santi, School of Medicine, Newcastle-on-Tyne; J. Symington, Minto House, Edinburgh; A. Blaney, Catholic University Medical School, Dublin; J. H. Teacher, University of Glasgow; J. Musgrove, University of Edinburgh; H. D. Rolleston, St George's Hospital; A. Thomson, University of Oxford. Misses Pieroy and Bale, London School of Medicine for Women.

Out of a total of 769 subjects examined the presence of Meckel's diverticulum has been noted sixteen times, or slightly over 2 per cent. Subjoined are the descriptions of the various examples noted.

Mr H. HUNTER, of Trinity College, Dublin, describes a case as follows:—The subject was an adult male, who suffered from a large femoral hernia on the left side. The diverticulum, with the greater part of the ileum and much of the sigmoid flexure of the colon, formed contents of the hernia.

The distance of the diverticulum from the ileo-cæcal valve was 49 inches; it sprang from the anterior aspect of the gut, close to its mesenteric attachment. Its length was $1\frac{1}{2}$ inch when inflated, and its diameter about $\frac{1}{2}$ an inch, but towards its lower end it expanded suddenly into a hammer-shaped extremity, whose largest diameter was $1\frac{1}{4}$ inch. The diverticulum had no connection at its extremity with the umbilicus or other part, nor was there any trace of such.

The next case is recorded by Mr F. H. Marson of Queen's College, Birmingham. The diverticulum was situated 34 inches from the cæcum, was $2\frac{1}{2}$ inches in length and $3\frac{3}{4}$ inches in diameter.

Mr SUTHERLAND, of Aberdeen University, records another case, but is unable to furnish further details.

Mr THELWALL THOMAS, of University College, Liverpool, describes a case which came under his observation. The diverticulum was situated 36 inches from the ileo-cæcal valve, was $2\frac{1}{2}$ inches long, and was adherent to the mesentery by a slight double fold of peritoneum, which was attached to the diverticulum for half its length, the tip of the diverticulum being rounded and free.

Dr SYMINGTON, of Edinburgh, sends notes of a case in which the diverticulum was situated 56 inches from the ileo-cæcal valve, was

TABLE VI.—Details regarding the Cases of Meckel's Diverticulum recorded.

		Sex.	Age.	Distance of Diverticulum from Cecum.	Character of Diverticulum.	Relation to Mesentery.
Mr H. D. Rolleston's Case,	1	Male.	4 weeks.	21 inches.	Cul-de-sac $\frac{1}{2}$ inch long; same lumen as bowel.	Lying in mesentery.
"	2	Male.	3 years.	24 inches.	Cul-de-sac dilated at end.	" " " " " " " " " " " "
"	3	Male.	16 years.	64 inches.	Cul-de-sac.	" " " " " " " " " " " "
"	4	Male.	21 years.	24 inches.	Cul-de-sac 2 inches long; lumen same as bowel.	Not recorded.
"	5	Male.	34 years.	31 inches.	Cul-de-sac 3 inches long; lumen	Away from mesentery.
"	6	Male.	37 years.	34 inches.	with ach 2 $\frac{1}{2}$ inch	
"	7	Male.	43 years.	70 inches.	Cul-de-sac lumen of bowel.	Lying in mesentery.
"	8	Female.	74 years.	34 inches.	Cul-de-sac lumen of bowel.	Not recorded.
"	9	Male.	75 years.	150 inches.	Cul-de-sac 3 inches long; lumen of bowel.	In mesentery.
"	10	Male.	80 years.	43 inches.	Cul-de-sac 3 $\frac{1}{2}$ inches long; end dilated; walls of extremely thickened.	Away from mesentery.
Mr W. Hunter's Case,	11	Male.	Adult.	49 inches.	1 $\frac{1}{2}$ inch long; diameter $\frac{1}{2}$ inch thick;	Free.
Mr F. H. Marton's Case,	12	Not recorded.	Not recorded.	24 inches.		Not recorded.
Mr H. Sutherland's Case,	13	Not recorded.	Not recorded.	30 inches.	and free.	Adherent to the mesentery by a double fold of peritoneum for about half its length.
Mr Thelwall Thomas' Case,	14	Not recorded.	Not recorded.	36 inches.	2 $\frac{1}{2}$ inches long, 3 inches in circumference; pointed at one side of its extremity.	Free.
Dr Symington's Case,	15	Not recorded.	Not recorded.	49 inches.	1 inch long.	Free.
Mr J. H. Teescher's Case,	16	Not recorded.	Not recorded.			

Total number of subjects examined, 769.

2½ inches long and 3 inches in circumference. The diverticulum was quite free, and somewhat pointed at one side of its extremity.

Mr J. H. TEACHER mentions a case where the diverticulum was situated 49 inches from the ileo-cæcal valve, and measured about 1 inch in length; it was perfectly free.

A very valuable addition to the returns relating to this question has been made by Mr H. D. ROLLESTON of St George's Hospital, who has sent in a record of 337 subjects, which he examined in the post-mortem room of that hospital. He has tabulated the details of ten instances of this condition which he met with, and the aforementioned cases have been included, so as to make the table as complete as possible.

In a note appended to his report Mr Rolleston draws attention to the fact that nine out of the ten subjects in which this anomaly existed were males, a fact which he says cannot be accounted for by the supposition that more examinations were made in males than in females, for as a matter of fact there was not much difference in the number of males and females examined. He further adds that there was nothing to suggest that the formation of the pouch was due to traumatism, such as partial strangulation, &c., and in no case was the diverticulum attached to the umbilicus, though in one case (No. 6) there was a fibrous cord, which might have been broken away from the umbilicus and subsequently contracted fresh adhesions.

In conclusion, the Committee desire to place on record their thanks to all those gentlemen by whose co-operation they have been enabled to publish the present Report.

The Secretary will be pleased at all times to receive any suggestions in regard to this or allied matters. Communications to be addressed to him at the Anatomical Department, Museum, Oxford.

THE THYRO-GLOSSAL DUCT OR "CANAL OF HIS."

BY C. F. MARSHALL, M.D., B.Sc., *House Physician to the Metropolitan Hospital, late Senior House Surgeon to the North-Eastern Hospital for Children, late Platt Physiological Scholar in the Owens College.* (PLATE I.)

HAVING recently had the rare opportunity of making an autopsy on a child in whom there was a so-called persistent "canal of His," I venture to publish a description of my specimen, in the hope of throwing some light on the morphology of this interesting malformation.

The child in question was a male, five years of age; he was admitted to the North-Eastern Hospital for Children, under Mr Bilton Pollard, for the purpose of having the "canal" excised. He however contracted diphtheria, and died before the operation could be performed. I here take the opportunity of expressing my great obligation to Mr Pollard for his generosity in permitting me to publish the case.

Before describing my specimen, I shall briefly refer to the more important accounts given by previous writers on the subject.

1. Raymond Johnson¹ describes two cases of "persistent lingual duct" which are typical examples of what is known to surgeons as the "canal of His." In both his cases there was an open sinus in front of the neck discharging mucus; from this a cord was found passing up to the hyoid bone. In both instances the cord had a patent lumen for a short distance; one was lined by stratified epithelium, the other was not. One case was a female, aged 15 years, in whom the sinus had been present for five years; the other was a female aged 6 years, with a sinus of two years' duration.

2. Concerning the developmental part of the question, His² has shown that the thyroid gland of man develops in three independently arising parts—(1) a median tubular outgrowth from the ventral wall of the pharynx, which forms the isthmus of the thyroid gland and also the lobus pyramidalis, when this exists. (2) Two solid lateral outgrowths which form the lateral lobes of the thyroid. The median portion he terms the *thyro-glossal duct*, and subdivides it into an upper portion leading from the foramen cæcum to the hyoid bone,

¹ *Lancet*, 10th May 1890.

² *Anatomie Menschlicher Embryonen*, iii. pp. 97-102, 1885.

Fig. 3.



which he names the *lingual duct*, and a lower portion, the *thyroid duct*, extending from the hyoid bone to the isthmus of the thyroid gland. His states that these ducts may persist in whole or in part, but he has never seen a case where the duct was patent for the whole distance from the foramen cæcum to the thyroid gland, it being always obliterated where it passes behind the hyoid bone.

3. In a later paper¹ His gives further details of the development, and shows that the *middle thyroid rudiment bifurcates at its lower end*, forming two lateral lobes at right angles to the main duct; these lateral divisions fuse with the lateral thyroid rudiments, and thus form parts of the lateral lobes as well as the isthmus of the thyroid gland.

4. Bland Sutton² describes the *processus pyramidalis* of the thyroid gland as being part of the original thyro-glossal duct.

Neither His nor Bland Sutton make any mention of the canal and sinus opening in front of the neck, which is known to surgeons as the "canal of His."

5. An entirely different explanation of the origin of the median canal and sinus is given by Kostanecki and Mielecki³ and also by Kanthack.⁴ According to these authors this structure must be regarded as a median fistula caused by deficient closure of the *sinus cervicalis*. The *sinus cervicalis* is a deep semicircular groove lying behind the pharyngeal region between the body and head of the embryo, and occupying its lateral and ventral surfaces. It is caused by the anterior visceral arches, especially the hyoid arch, overlapping the posterior ones, and it may be compared to an opercular cavity. Normally it becomes obliterated, but, according to the above writers, in some cases its median portion persists and gives rise to a median fistula.

Kanthack suggests that a complete median fistula may be due to a tear through the closing membrane of the second branchial pouch or groove into the *sinus cervicalis*. No direct evidence, however, is quoted in support of this suggestion.

DESCRIPTION OF SPECIMEN.

In the anterior median line of the neck, about one inch above the sternum, was a sinus discharging a small quantity of mucoid fluid. This had been noticed for about a year, and had discharged at irregular intervals, becoming closed up in the intervening periods.

From this opening a hard cord could be felt extending up to the hyoid bone. On dissecting the front of the neck this cord

¹ *Archiv für Anatomie und Entwicklungsgeschichte*, 1891, pp. 26-32.

² *Dermoids*, pp. 79-83.

³ *Virchow's Archiv*, vols. 120, 121.

⁴ *Jour. Anat. and Phys.*, Jan. 1891.

was found to be tubular and patent up to within half an inch of the hyoid bone: the upper end was firmly attached to the hyoid bone, the lower end dilated into a thin-walled sac opening on to the surface at the external sinus. The sac and tube lay between the skin and the anterior layer of deep cervical fascia: at no place was there any connection with the thyroid gland.

By dividing the hyoid bone the tube could be traced as an ill-defined fibrous cord on the dorsal surface of the hyoid bone, to which it was closely attached, and passing through the substance of the tongue up to the foramen cæcum. About three quarters of an inch from the foramen cæcum it again became patent and continued so up to the surface of the tongue. The canal was thus open at both ends but obliterated in the middle part of its length.

On further dissection a lobus pyramidalis was found passing from the left side of the isthmus of the thyroid to the hyoid bone, the upper end being united to the median fibrous cord at the same place as the above-mentioned canal. In other words, the fibrous cord behind the hyoid bone was continuous both with the pyramidal lobe of the thyroid and with the tube leading to the superficial sinus.

The above description will be made more clear by reference to the figures (Plate I.).

Fig. 1 shows the canal and sac exposed by reflecting the skin from the middle line of the neck.

Fig. 2 shows a dissection of the thyroid gland and under surface of the tongue. The lobus pyramidalis is seen arising from the left side of the thyroid gland; the upper end of the canal is joined by the pyramid, and the two structures are continued onwards as the median fibrous cord, which is exposed by dividing the hyoid bone. Further on the canal is seen to become patent and pass up to the foramen cæcum.

Fig. 3 is a slightly diagrammatic view of the parts in question. The tongue and upper canal (lingual duct) are shown in vertical section as far down as the hyoid bone; below the hyoid bone the parts are seen in elevation. The thyro-glossal duct is here shown in its whole length, the shaded portion representing the obliterated part which I have referred to as the fibrous cord.

MICROSCOPIC EXAMINATION.

Sections of the canal in its middle portion show the following structure. Externally it is composed of very dense fibrous tissue; internally there is an irregular lumen not enclosed by any definite epithelial layer. The main substance of the canal consists of an irregular arrangement of fibrous tissue, numerous blood-vessels, and masses of cells. The cells vary in size and shape, but the majority are more or less rounded in outline with distinct nuclei. In some places they appear aggregated together in large irregular masses with very little fibrous tissue; in other places the fibrous tissue is abundant and the cells few in number. The whole structure gives the idea of *embryonic or imperfectly developed glandular tissue*.

Sections of the pyramid show that it is composed of ordinary thyroid gland tissue.

Sections of the fibrous cord show nothing but fibrous tissue and no trace of any duct.

No direct connection exists between the pyramid and the canal of His at their point of junction with the fibrous cord.

REMARKS.

Let us now consider what light these facts throw on the explanation of the origin of the "canal of His." The possible views of the origin of this structure may be reduced to three:—

1. That it belongs developmentally to the thyroid gland.
2. That it is formed by persistence of part of the sinus cervicalis.
3. That it is of independent origin.

It appears to me that all the facts shown in my specimen tend in favour of the first view, the main points being (1) that the canal and the pyramidal lobe are both equally firmly united to the median fibrous cord; (2) the apparently glandular structure of the canal seen on section; (3) the patent foramen cæcum and short canal leading from it representing the lingual duct.

It hence appears a reasonable explanation that *the canal of His is the remnant of one of the bifurcations of the original*

median thyroid rudiment, the other bifurcation forming the pyramidal lobe of the thyroid gland. The imperfectly developed gland tissue of which the canal seems to be composed is strong evidence in favour of this view. This explanation is also supported by the fact that the pyramid, when present, is always attached to one side of the thyroid gland and is not really median. In my case it was attached to the left side: His¹ figures a case where it is attached to the right side and forms part of a persistent thyro-glossal duct. Professor His has moreover kindly informed me by letter that he has seen a case in which there were two fully developed pyramids, one on each side.

The view that the canal is formed from the sinus cervicalis can I think only be regarded as a suggestion, and has at present no direct evidence to support it. Moreover, the history of these cases is strong evidence against this view. In Mr Raymond Johnson's cases and in my case the sinus was not noticed till the child was several years old: now, on the supposition that they are congenital fistulæ, we should expect them to be most marked, or at any rate present, at birth.

Again, the account given by Kanthack of the sinus cervicalis bursting through into one of the branchial clefts is without parallel in embryology, and can hardly claim serious consideration until direct evidence in support of it is forthcoming.

Against the view of independent origin is the presence of the deep foramen cæcum, the presence of a pyramid to the thyroid, and other facts mentioned above, all showing that the thyroid gland had in this case developed in an exceptional manner.

CONCLUSION.

In the absence of evidence to show whether a pyramid to the thyroid gland is always present in these cases, it is impossible to come to a definite conclusion, but I think that the facts shown by my specimen tend in favour of the view that the so-called "canal of His" is a remnant of the middle thyroid rudiment of His. It is not difficult to imagine that this may gradually become dilated at its lower end into a sac by the

¹ *Anatomie Menschlicher Embryonen*, iii. p. 100, fig. 67.

secretion of mucus from the wall of the canal, and that this sac ultimately causes the skin to give way by its pressure till a sinus is formed.

If this explanation is correct it is easy to see that a persistent thyro-glossal duct may be due to the persistence of either of the two lobes formed by the bifurcation of the median thyroid rudiment. In the case described by His¹ it is the right lobe or pyramid of the thyroid, which forms the lower part of the thyro-glossal duct, the left lobe of the thyroid rudiment having become obliterated in his case. In my case both bifurcations had persisted, the one as a pyramid, the other as the "canal of His."

In conclusion, I must express my thanks to my brother, Professor Milnes Marshall, for much help in connection with the embryological bearings of the subject. My thanks are also due to Professor His and Mr Bland Sutton.

EXPLANATION OF PLATE I.

(All the figures are natural size.)

Fig. 1. Canal of His exposed by dissecting the skin from the median line of the neck. *c*, canal; *h*, hyoid bone; *s*, sac with open sinus.

Fig. 2. Dissection of the thyro-glossal duct, thyroid gland, and base of the tongue. *c*, upper end of canal of His; *f*, fibrous cord; *h*, hyoid bone; *l*, lingual duct opened and fixed by pins; *m*, muscles cut through at base of tongue; *p*, pyramidal lobe; *t*, thyroid cartilage; *th*, thyroid gland; *tr*, trachea.

Fig. 3. Semi-diagrammatic figure: the upper parts are in vertical section, the lower part in elevation; *f. c*, foramen cæcum; *s*, sac with sinus opening in front of neck; other letters as before.

¹ *Loc. cit.*, fig. 67.

**THE OCCURRENCE OF AN ADDITIONAL PHALANX
IN THE HUMAN POLLEX.** By **BERTRAM C. A. WINDLE,**
M.A., M.D. (Dubl), *Professor of Anatomy in the Queen's
College, Birmingham.* (Plate II.)

SOME time ago the man whose hands are figured in the accompanying illustrations¹ was sent to me for inspection. His description of his condition was that he had "five fingers and a thumb on one hand, and five fingers and no thumb on the other." On examining him I found the following condition of affairs. Left hand—the thumb bore on the radial side of its metacarpal bone a supernumerary digit, provided with a well-formed nail, and consisting of two phalanges, provided with movable articulations with one another and with the metacarpal bone. The thumb itself was nearly as long as the index finger, the appearance of which it simulated, and was provided with a metacarpal bone and with three phalanges, movable articulations existing between each of the members. The digit in question, though simulating the appearance of the other members of the series, was yet functionally a thumb. Right hand—the normal number of digits was present, but the radial digit or thumb, like that on the other hand, had a metacarpal bone and three phalanges, the articulations between the members being movable. In its relation of position to the other members of the series, this digit was unmistakably a thumb, and so far as could be seen it possessed the usual

	Metacarpal.	1st phal.	2nd phal.	3rd phal.
Left hand—				
Radial pollex,	...	3·0	2·5	...
Ulnar pollex,	4·5	5·0	2·5	2·3
Index, . . .	6·0	5·0	2·5	3·0
Right hand—				
Pollex, . . .	5·0	4·5	1·8	3·0
Index, . . .	6·0	5·0	3·0	3·0

¹ I ought to mention that these drawings were made for me by my late pupil, Mr W. M. Sadler, whose early death I much regret.

Fig. 1.

Fig. 2.

Fig. 3

Fig. 4.



muscles of that digit. It was not so long in proportion as the corresponding digit of the other hand. The preceding table gives the measurements.¹

The unusual nature of this case having much interested me, I made a careful search through teratological literature for others of a similar nature. As the condition is a rare one, I think it may be useful briefly to give the details of the cases which I have been able to discover, more especially as I shall have to allude to them in discussing the points for consideration to which they give rise.

Case 1 (Struthers, *Edin. New Phil. Jour.*, 1863, p. 83. Also mentioned in *References to Papers on Anatomy*, by Professor Struthers, pub. 1889, sec. 22).—A.S., has six digits on each hand and on each foot. One of the thumbs presents three phalanges on each hand. The two thumbs are supported on one unbifurcated metacarpal bone. The thumb next the forefinger is clearly felt to have three phalanges, while the lesser thumb has two phalanges. It is the same on both hands. The greater thumb is $2\frac{3}{4}$ inches in length on the left hand, and $2\frac{1}{2}$ on the right; the lesser thumb is 2 inches in length on both hands. The circumference of the greater thumbs on the left and right sides, respectively, is $2\frac{1}{2}$ and $2\frac{1}{4}$, that of the lesser thumbs being 2 inches. The two thumbs are webbed at their base. In each hand, it is the thumb next the forefinger which is used. There is some evidence of heredity in the condition.

Case 2 (*same references*).—J.J., aged 21, has the thumb on both hands of unusual length and form. Each possessed an additional joint, giving three phalanges besides the metacarpal bone, the additional bone being placed in the position of a middle phalanx. The metacarpal bone is $2\frac{1}{4}$ inches in length, and appears to be quite normal. The first phalanx is $1\frac{3}{4}$ inch in length, and is, therefore, longer than usual. The additional bone, occupying the position of a middle phalanx, is broader on the inner, or radial, side than on the side next the index finger, having a triangular or wedge-shaped figure, which gives the distal phalanx an inclination towards the index. It measures along the radial side $\frac{5}{8}$ inch, along the ulnar side $\frac{1}{4}$ inch, and $\frac{1}{2}$ inch along the middle. The position of the base of this wedge-shaped additional bone is shown by a double protuberance on the radial side. Between these a depression may be felt corresponding to the short shaft between the articular ends. The distal phalanx is an inch in length. The measurements were made exactly from the joints, avoiding the error of including the knuckles twice. When the thumb is straightened, its point passes a sixth of an inch beyond the joint between the proximal and middle phalanges of the index finger.

¹ These measurements may not be absolutely correct as they were made from casts of the hands, but they are at least relatively accurate.

The thumb of the right hand scarcely advances so far as that joint. The unusual length of the thumbs in this case is gained by the proportionately greater length of the proximal phalanx and by the presence of the additional bone, while the distal phalanx is a little shorter than usual. At the joint on the proximal side of the additional phalanx there is the usual extent of flexion and extension. Between it and the distal phalanx passive motion is free and readily felt in both thumbs, although it cannot be carried so far as to cause an angle or additional knuckle. Some motion in the lateral direction can also be made at this joint. The utility of the thumb is not impaired. The fingers are longer than usual (their lengths, from the metacarpo-phalangeal articulation, are—forefinger, $3\frac{7}{8}$; middle, $4\frac{3}{8}$; ring, $4\frac{1}{4}$; little, $3\frac{1}{2}$ inches. The whole hand is 8 inches in length, present the usual proportionate length, and have three phalanges each. A maternal aunt had the same kind of thumb on the right hand, being the only instance of the occurrence of the peculiarity in any relative of the family.

Case 3 (Rüdinger, *Beiträge zur Anatomie des Gehörorgans, der venösen Blutbahnen der Schädelhöhle, so wie der überzähligen Finger*, München, 1876, s. 25. Quoted by C. Hennig, *Mitth. aus der Heilanstalt*, "I. Von der Überzahl der Finger und Zehen und von Dreigliedrigen Daumen," Leipzig, 1880, s. 2).—The subject, an adult male, had the first digit on each hand doubled, and each of these digits was provided with three phalanges. Work was performed with the digit lying next to the index finger, and this was more stoutly built than the radial thumb. The three phalanges of these four digits showed no resemblance to the normal members of a thumb. The radial metacarpal of the thumb was somewhat stronger than the ulnar, and drawn from the dorsal towards the palmar surface resembled the metacarpal bone of a thumb; otherwise, both the metacarpals of these thumb-digits showed all the characteristics of the metacarpal bones of the fingers. In the right hand of this man there were three supernumerary carpal bones, articulating with others of the series; two of these lay in the first row, distal and dorsal to the scaphoid and between it and the lunare; the third, which lay between the trapezium and trapezoid, was only visible on the dorsal surface. The left carpus possessed two supernumerary bones, one between the scaphoid and lunare, and the other between the trapezium and trapezoid.

Case 4 (same references).—The seven-year old daughter of the man whose case has just been described. There was the same malformation on both hands; but in addition there was in the left hand a seventh finger. This was a stump-like appendage situated on one of the thumb digits, with two members possessing only the power of passive motion and furnished with a well-formed nail.

Case 5 (Otto, *Sexcentorum Monstrorum Descriptio Anatomica*, No. 256).—The case was that of a man, aged 24. In both hands the annularis, medius, and index were fused, the last being represented by

a small stump, which was more distinct on the left than on the right hand. In spite of the appearances there was really a superfluity of digits, each hand possessing six, or rudiments of six. Each hand had two trapezia. In the right hand the radial pollex possessed three phalanges, and a metacarpal which articulated with the radial and smaller trapezium and with the ulnar pollex. The ulnar pollex had a metacarpal which articulated with both trapezia, the index, and the radial pollex. It also possessed one long phalanx. The second phalanx of the radial pollex was very markedly smaller than any of the other members. The index had a metacarpal bone and one phalanx. The left hand possessed a radial pollex consisting only of a metacarpal bone which articulated in a similar manner to the corresponding bone of the other hand. The ulnar pollex had a metacarpal with the same articulations as on the right, and three phalanges, the second being the smallest, though the difference was not so marked as on the left. The index had a metacarpal and one phalanx. With regard to the musculature, in both hands both pollices received a slip from the flexor longus pollicis, and neither had any tendon from either of the flexors of the digits. The right hand had the abductor, flexor brevis, opponens, and part of the adductor attached to the radial pollex, the remainder and greater part of the last-mentioned muscle going to the ulnar pollex. Extensores primi internodii and ossis metacarpi pollicis were attached to the radial, and secundi internodii to the ulnar, pollex. Extensores carpi radiales longior and brevior were attached to the index and medius respectively. In the left hand the abductor and opponens were attached to the radial pollex, the adductor solely to the ulnar. Extensores ossis metacarpi and secundi internodii pollicis were attached to the radial pollex, and extensor primi internodii to the ulnar. Extensores carpi radiales longior and brevior were attached as in the other hand.

Case 6 (Gegenbaur, *Morph. Jahrb.*, Bd. xiv. s. 394).—The subject possessed four normal fingers and two abnormal. The latter belonged to the radial side of the hand, and were united to one another throughout their length (syndactylous), so that both together acted as a functional thumb. The ulnar was larger than the other ("præpollex"), and lay on its dorsal surface, so that looked at from the palmar surface only one was visible. The præpollex was, compared with the other digits, a very slender finger. Both abnormal digits possessed metacarpals of greater length than those of the other fingers. The præpollex possessed two phalanges, and its metacarpal articulated promixo-laterally with the metacarpal of the pollex. Its proximal uncartilage-clad extremity lay opposite the trapezium, but did not articulate with it. The stronger pollex possessed a metacarpal and three phalanges, was opposable to the other four digits, but amphiarthrotically united to the carpus, not having a saddle-joint. The remaining four fingers showed slight peculiarities, the medius alone articulating with the os magnum. A centrale was present.

Case 7 (Wenzel Gruber, *Virchow's Archiv*, Bd. lxxxvi. s. 495).—There was a supernumerary pollex on each hand, those on the right both possessing two phalanges. The radial pollex of the left hand had three phalanges, the last possessing a spur-like process on its radial side, which the writer states was apparently a second phalanx fused to it. I shall refer further to the articulations and musculature of this case.

Case 8 (Wenzel Gruber, *Bull. de l'Acad. Imp. des sc. de Petersbourg*, Tome xvi. Col. 359–368).—I have only been able to give the brief reference made to this case in the paper in *Virchow's Archiv*, Bd. xcv. s. 186). The subject was living. The left hand possessed six metacarpals with seven (*sic*) fingers, one three-phalanged pollex and five three-phalanged digits.

Case 9 (Annandale, *Malformations of the Fingers and the Toes*, p. 29).—The subject was a girl, aged 13, otherwise well formed. The hand was perfectly developed in every way, except that the thumb resembled a long forefinger, having three phalanges. "Since then," he says, "I have met with other similar cases."

Case 10 (Farge, *Gaz. hebdom. de méd. et de chir.*, 1886, No. 4, p. 61. Quoted by Fackenheim, *Jenaischen Zeitsch. f. Naturwiss.*, Bd. xxii. N.F. xv. s. 356).—A family of the name of Cady evidenced hereditary polydactyly. The paternal grandmother possessed four thumbs. The father had instead of thumbs, fingers with three phalanges. He had six children as follows:—(1) A boy with normal hands; (2) a boy with a supernumerary thumb on the left hand; (3, 4, 5) two boys and a girl, who, like the father, had no thumbs, but instead of these three-phalanged fingers; (6) a boy possessing five metacarpals with three phalanges belonging to each, and, besides, a rudimentary 6th digit forming a projection under the skin, and representing a radial pollex.

In addition to these cases, I should mention that Burt Wilder¹ states that "Dubois describes a case (*Arch. de Méd.*, April 1826) which is referred to by Fort (*Difformités des Doigts*, p. 58, 1869), and in the cabinet of the Boston Society for Medical Improvement is a plaster cast of another case which came under the observation of Dr B. E. Cotting, and was described by Dr J. B. S. Jackson (*Catalogue of Museum of Med. Imp. Soc.*)." I regret that I have been unable to refer to any of the references just mentioned.²

¹ "Intermembral Homologies," *Proc. Bost. Soc. Nat. Hist.*, xiv. 154. I have to thank Professor Howes for drawing my attention to this paper, as well as for other kind assistance.

² Since this paper was in type, I learn that Dr Shepherd exhibited at the Montreal Medico-Chirurgical Society (April 2, 1891) the left manus of a pig with six digits and a well-developed trapezium. The pollex possessed three phalanges.—(Note in *Medical Press*, Sept. 9, 1891.)

It may now be well briefly to sum up the salient features of the cases which I have detailed, and this will be most conveniently done in a tabular form.

Table of Cases of Three-Phalanged Pollices.

Case.	Hand.	No.	With Spny.	Rad.	Uln.	With-out.	Notes.
Author's.	both.	2	1	...	1	1	
I.	both.	2	2	...	2	...	Hereditary.
II.	both.	2	...	...	...	2	Hereditary.
III.	2 on each.	4	2	both.	...	...	Herd., a rudy.
IV.	2 on each.	4	2	both.	...	...	7th rad. digit.
V.	both.	2	2	1	1	...	
VI.	1 (?which)	1	1	...	...	...
VII.	left.	1	1	1	1	...	Supy. plx. right.
VIII.	left.	1	1	?	?	...	
IX.	...	1	...	...	...	1	
X.	both.	2	...	...	...	2	
X., a.	both.	2	...	...	...	2	
X., b.	both.	2	...	...	...	2	Hereditary.
X., c.	both.	2	...	...	...	2	
X., d.	both.	2	2	...	2	...	
		30	14	2	7	12	

It will be observed from the above table that the three-phalanged pollex may exist (1) alone and representing the normal pollex, or (2) with a supernumerary pollex. In the latter case both pollex and supernumerary or præpollex may possess three phalanges (Cases 3 and 4), or the three-phalanged digit may be the ulnar of the two, or more rarely, the radial. It will also be noted that, as in polydactylism, the influence of heredity is met with in several of the cases.

I propose now to consider several points of interest which are raised by the consideration of this subject:—

I. Nature of these three-phalanged digits.

At the outset, we are met with the question as to whether these three-phalanged digits should be considered as of the nature of thumbs or not. In the case quoted from Rüdinger, that author states it as his opinion, that the condition in question is not one of reduplication of the thumbs, but of increase in number of the ordinary digits. This distinction appears to me to be more metaphysical than real; and, moreover, I do not think that it is in any way borne out by the facts.

One of his cases is, undoubtedly, somewhat difficult of explanation; I allude to the second, in which rudiments of seven fingers were present. I have not been able to see the original account, and can only, therefore, venture to suggest that possibly the rudimentary digit may have been the præ-pollex; the second, the pollex; the third, the index, and so on to the ulnar side of the hand, where the last finger would be a postminimus. In this case we should have had to do with an instance of a heptadactylous manus of the type suggested by Bardeleben, which will be again referred to in a subsequent section of this paper. In any case, however, this instance is an isolated one. Of the remainder, it will be noticed that in twelve cases, the three-phalanged digit replaced the normal pollex and functioned as a thumb, being in the instances, where any note is made of the fact, opposable to the other digit. To call such a digit an instance of a double index with (presumably) absent pollex, is, to my mind, a misuse of terms, unless, indeed, we are to confine the term pollex to a two-phalanged digit, a limitation for which I can see no justification. In a second group the three-phalanged digit is radial, and the normal thumb has two phalanges. If this last be not a pollex, it will be necessary to adopt the double hypothesis that the index is doubled and that one of the two has lost a phalanx. This leaves the group where the three-phalanged digit is ulnar to a supernumerary having two or less phalanges, a group, the members of which, might with more reason be claimed as instances of doubled index. But a consideration of the musculature in cases of double pollex will, I think, establish the fact that these digits are much more of the nature of pollices than of that of the other digits. The additional phalanx is, of course, only an incident in a supernumerary pollex, and we may, therefore, consider the musculature of double thumbs whether three-phalanged or not. As the facts are of importance, I here give Gruber's tables, which I have amplified by adding the conditions in two cases published by him in a subsequent paper to that in which the table was given, as well as the case dissected by Otto.

TABLE I.

Case.	Cases with a Double Metacarpal			
	To Radial Poll.	To Ulnar Poll.	To both Poll.	Anomalies.
3. ¹	E. oss. meta- carpi. E. primi intern. Abductor. Opponens.	E. secundi in- tern.	Flexor longus.	Abd. divided into abd. and fl. prop. poll.; rad. fl. br. only an ulnar belly. Double interpoll.
4.	Abductor.	E. oss. meta- carpi. EE. pr. et sec. intern. Opponens. Flexor brevis. Adductor.	Flexor longus.	Abd. br. as above divided into two.
9.	E. oss. meta- carpi. E. primi intern.	Adductor. Flexor brevis.	Flexor longus. Ext. longus.	Abd. separated in two below. Two- bellied opponens. Two-layered add. and interpolli- caris.
Otto. Rt.	Abductor. Flexor brevis. Opponens. Adduct. (part). EE. pr. et sec. intern.	Adductor (part). E. sec. intern.	Flexor longus.	
Otto. Lt.	Abductor. Opponens. E. oss. meta- carpi. E. sec. intern.	Adductor. E. primi intern.	Flexor longus.	

TABLE II.

Case.	Cases with a Single Metacarpal			
	To Radial Poll.	To Ulnar Poll.	To both Poll.	Anomalies.
1.	E. primi intern. Opponens.	E. sec. intern. Adductor.	Flexor longus. Abductor. Flexor brevis. (E. oss. meta- carpi.)	Interpollic.
2.	E. primi intern. Abductor. Opponens.	Adductor.	Flexor longus. E. sec. intern.	Slips from uln. belly of fl. br. and add. to rad. poll.
5.	... ..	EE. oss. meta- carpi et sec. intern. Opponens. Flexor brevis. Adductor.	Flexor longus. E. primi intern. Abductor.	

¹ The numbers are those of Gruber's cases.

TABLE II.—*continued.*

Case.	Cases with a Double Metacarpal			
	To Radial Poll.	To Ulnar Poll.	To both Poll.	Anomalies.
7.	E. primi intern. Abductor.	E. sec. intern.	Flexor longus. Opponens. Flexor brevis. (E. oss. meta- carpi.)	Abd. div. below two-bellied oppo- nens. Double interpoll.
8. ¹	Abductor.	E. sec. intern. Int. pr. volar. Adductor. Flexor brevis.	Flexor longus. E. primi intern.	Interpoll.
9.	Abductor. E. primi intern. Opponens. Adductor.	... .. E. sec. intern.	Flexor longus.	

Wenzel Gruber sums up the account of the musculature of his cases by saying "the arrangement of the flexor longus is constant or almost so in all the cases, and so is that of the abductor and adductor. The arrangement of the extensor secundi internodii frequently (six-ninths to seven-ninths of the cases) is the same. In more than half the cases the interpollicaris is present, and that in either a single or double condition. Exceptionally in hands with a supernumerary pollex, a supernumerary extensor pollicis et indicis, and also the interosseus primus volaris, may exist." The nature of the musculature of these cases of double pollex is, I think, an exceedingly strong argument for the explanation of their value in the series of digits which has been suggested above. The following points should be specially noted:—(1) The short muscles normally belonging to the pollex are fairly evenly divided between the two pollices. The interpollicaris passing between the two appears to be a dismemberment of the adductor, and additional weight is lent to this by the fact that in Case 6 where the adductor is dilaminated, so also is the interpollicaris. (2) The extensors are also divided between the two pollices. (3) The tendon of the flexor longus always divides into two portions, one for either pollex. (4) Neither pollex receives in any case a tendon from either of the flexors of the digits or from the extensor communis digitorum. (5) In the case where they are mentioned the carpal extensors

¹ Cases 8 and 9 are from *Virchow's Archiv*, Bd. xcv. s. 186.

are not connected with the ulnar pollex, but pass to the next two fingers in the series. The facts, then, seem to point to the conclusion that these supernumerary digits are both really of the nature of thumbs, or perhaps it would be more accurate to say that they are the first and second digits of a hexadactylous manus. In any case there appears to be no reason for supposing that the ulnar of the two is a reduplication of the index finger.

II. *The absent member of the normal thumb.*

In a paper from which quotation has already been made, Burt Wilder discusses the question as to what constitutes a digit or dactyl, and points out that whilst "among the mammalia, the vast majority of those digits and dactyls about which no question can arise, consist of three phalanges, are visible to the eye as subdivisions of the distal extremity of the member, and perform some obvious function in the economy of the animal; the ordinary mammalian digit or dactyl being thus functional, visible, and trimerous, there are many exceptions to this definition." Arguing, however, from the trimerous nature of the great majority of digits, most writers on anatomy seem to be agreed that the typical pollex would possess a metacarpal and three phalanges. The three-phalanged pollex might, therefore, be viewed as a return to the typical condition. On the other hand, as Professor Howes has been good enough to point out to me, it is very questionable whether such a condition can in any just sense be called reversional, since, as he says, "if the appearance of a third phalanx be really reversional, it is strange that the palæozoic Stegocephali should not possess more than two." In fact, the Cetacea are the only members of the mammalia possessing in some instances more than two phalanges in the pollex (*Catodon*, *Physeter simus*, *Globiocephalus*). Waiving the question of atavism, it is legitimate to enquire into the nature of the morphology of the members of the normal pollex, in connection with those supplied with three phalanges. Differing views have been put forward on this question by writers on anatomy. Humphry,¹ after giving several reasons in favour of the view that the proximal member corresponds with a phalanx, says—

¹ *Human Skeleton*, p. 395.

"It is evident, in short, that the first bone is neither truly a metacarpal bone nor a phalanx, but is intermediate between the two. Taking all things into consideration, it is perhaps most correct, as it is certainly most convenient for description, to continue to call it a metacarpal bone, and to consider that the second phalanx, with its flexor perforatus tendon, is the digital segment which is missing in the thumb."

And in a note he says—

"This view derives confirmation from comparative anatomy."

Sappey¹ says—

"On peut le considérer, avec MM. Joly et Lavocat, comme composé d'un métacarpien rudimentaire et de la première phalange du pouce. Le métacarpien et la phalange ont chacun pour origine un point osseux distinct. Mais ces deux points, au lieu de rester indépendants, se soudent l'un à l'autre. Le point d'ossification supérieur, ou le métacarpien proprement dit, représente à peine le sixième de l'os; le point d'ossification inférieur, ou la première phalange du pouce, en forme la presque totalité. Ainsi constitué, il appartient beaucoup plus aux phalanges qu'aux métacarpiens, et devait offrir surtout les caractères qui distinguent les premières; ce sont ces caractères qu'on retrouve en effet sur son corps et son extrémité inférieure."

Henle² considers that the controversy has been settled by the observations of Uffelmann, to which I shall allude more particularly later on, and says—

"Der Mittelhandknochen des Daumens weder ein eigentlicher Mittelhandknochen noch eine Phalange, sondern ein Repräsentant beider ist."

MacLise³ says—

"I have reason to believe that the bone which we term the metacarpal bone of the thumb in one animal is the true homologue of the first phalanx of the finger (in his figure), and for this reason, viz., that the metacarpal bone of the human thumb is constituted of two ossicles, which have become consolidated. If we class the hindmost ossicle with the other metacarpal bones, the foremost ossicle will represent the first phalanx of the other fingers, and this will give three phalanges to the thumb, as to the other fingers. It is worthy of notice, that the so-called metacarpal bone of the thumb corresponds as to the nucleary deposit with the first phalanx of the finger."

Struthers, discussing this question in connection with the cases of three-phalanged thumbs already quoted, says⁴—

¹ *Traité d'Anatomie*, i. p. 391.

² *Hdb. der Anat. des Menschen*, pt. i. s. 261.

³ *Todd's Cyclop. Anat. and Phys.*, art. "Skeleton," p. 663.

⁴ *Op. cit.*, p. 111.

"The facts in comparative osteogeny show, that the position of the epiphysis is decisive in establishing the view that the bone which is wanting in the human thumb and great toe, and in the internal digit of other five-toed mammals, is the metacarpal and metatarsal, although custom and convenience lead us to apply these terms to the bone which homologically is the proximal phalanx."

Turning now to the cases of three-phalanged pollices, the chief noteworthy point in the present connection is that in those instances where the condition is sufficiently described, the smallest of the members is the middle or second phalanx, this being so markedly the case in one of Struthers' subjects, that he speaks of "the additional bone occupying the position of a middle phalanx." Now, as in normal digits, the middle phalanx is considerably larger than the distal, it would from this appear that this smaller second phalanx was the intruder, and thus that it, as Humphry suggests, is the missing member in the human pollex. The question is, however, one which can only be satisfactorily settled from embryological considerations, and it may, therefore, be well to review it in the light of recent observations as to the nature and origin of the phalanges and of certain structures connected with the articulations.

Boulenger¹ having published a paper in which he confirmed former statements as to the existence of a supernumerary phalanx between the ultimate and what is normally the penultimate one in the Polypedatinæ, Professor Howes and Mr Davies were led to investigate the morphology and genesis of supernumerary phalanges.² In this paper they have shown that a structure, such as the fibrous pad of the common frog, may be looked upon as the homologue of the skeletal supernumerary phalanx of the higher Ranidæ and Hylidæ. From the examination of various amphibians, they conclude that

"the phalanges and syndesmoses are, together with their investing sheath, differentiations of a continuous and common blastema; and that the syndesmoses, while intimately related to the sheath, are formed, not as ingrowths of the same but as differentiations of that mass from which the phalanges are derived, and that they differ from these, initially, only in degree of elongation."

These facts show that the supernumerary phalanx, the normal phalanges, and the syndesmoses are all on a developmental

¹ *Proc. Zool. Soc.*, 1888, p. 204.

² *Ibid.*, p. 495.

equality. The last named must then be looked upon as structures which, despite secondary changes, would be liable to take on more or less completely the condition of a phalanx. Indications of this are not wanting; for Leydig, in describing the supernumerary phalanx (his "Zwischengelenkknorpel") in *Hyla Arborea*, asserts—

"Er fehlt selbst bei Reptilien nicht, wo ich denselben früher übersehen hatte; gegenwärtig kenne ich ihn bei *Lacerta* (*L. muralis* und *Platydictylus mauritanicus*."

And in the conclusions at the termination of their paper they state—

"1. That the supernumerary phalanx of the Anura is a true phalanx, and, at the same time, structurally identical with the interphalangeal syndesmosis of these and the other Amphibia, all transitions between the two being represented in adults of the living forms. 2. That the syndesmoses and phalanges are differentiations of a common blastema. 3. That the facts of development herein recorded indicate a possible intercalary origin, from inter-articular syndesmoses for supernumerary phalanges in general."

In a paper on the development of the joints in birds and mammals, Hepburn,¹ though not dealing with the question of supernumerary phalanges, has also shown that the bone-matrices and the articular disc possess a tissue continuity, and are derivatives of a common blastema, of which the articular disc is at first the undifferentiated form; and, further, that the articular disc may develop into a plate of cartilage and form a synchondrosis, or may differentiate into fibrous tissue and form a syndesmosis or synarthrosis, or, finally, may partly cleave and form a joint-cavity. Again, he has shown that the proximal and distal segments of the articular disc develop into the articular cartilages of the joint, and probably form part, if not all, of the epiphyseal ends of the bones, that the circumference of the articular disc develops into the capsule of the joint, and that inter-articular fibro-cartilages and ligaments are derived from the articular disc as the result of the modifications of the joint-cavity. From the researches of these authors it follows that various structures in the digits are of the same morphological value as the bony segments, and that in them we may find a clue to the origin of the additional phalanx occasionally met

¹ *Jour. of Anat. and Phys.*, vol. xxiii. p. 507.

with in the pollex. But in addition to what has just been stated, there is evidence to show that segments of the digit which are present in the foetus may abort and be non-existent in the adult. Thus Wiedersheim states,¹ that though the third finger in all existing carinates has only one phalanx as compared with four in archæopteryx; in embryos of the duck, a cartilaginous rudiment of a second phalanx is present in the third finger of the manus. Amongst the mammalia Kukenthal has shown that in *Globiocephalus melas*,² and in *Beluga leucas*,³ there is a reduction in the number of phalanges in passing from the foetal to the adult condition. Taking these last-mentioned facts in connection with the observations of Howes and Hepburn, it would seem probable that some structure exists in the pollex which is capable by further and independent development of giving rise to an additional segment. It now remains to enquire whether any trace of such a structure is to be met with in the development of the thumb. It has already been mentioned that Sappey considered the proximal segment of the pollex as consisting of a metacarpal, the proximal epiphysis and a phalanx, the diaphysis, the two being fused to form one bone in the adult. In this description, however, he took no account of the distal epiphysis. Thomson,⁴ states that

“from the circumstance that in all favourable instances which have come under my notice at ages between seven and fifteen years, traces of the separation of the distal epiphysis have been found in both the first metacarpal and metatarsal bones, I am inclined to look upon the disposition at least to the formation of such epiphyses as general; while in a certain number of instances, the proportion of which I cannot at present determine, the separation by cartilage of a bony epiphysis is at one time complete.”

A more complete account of the behaviour of this end of the bone is given by Uffelmann,⁵ who has shown—

“Dass in einem gewissen, mehrere Jahre dauernden Stadium der Entwicklung der Anschein eines besonderen Knochenkerns in

¹ *Comp. Anat. of Vertebrates*, Eng. ed., p. 107.

² *Anat. Anzeiger*, 1888, s. 638.

³ *Ibid.*, 912.

⁴ *Jour. of Anat. and Phys.*, vol. iii. p. 131.

⁵ *Der Mittelhändknochen des Daumens*, Göttingen, 1863. Quoted by Henle, *loc. cit.*

Capitulum besteht, ohne dass ein solcher jemals in Wirklichkeit vorhanden wäre. Beim Neugeborenen ist die untere Chondroepiphysis etwas weniger hoch als die obere, umgekehrt wie bei den übrigen Mittelhandknochen. Im dritten Lebensjahre zeigt sich der Knochenkern in der oberen Chondroepiphyse und im sechzehnten Jahre, früher als irgend eine andere Epiphyse der Handknochen, verwächst er mit der Diaphyse. Am unteren Ende des Daumen-Mittelhandknochens wächst, zwischen dem Ende des ersten und dem dritten Lebensjahre, von der Endfläche der Diaphyse ein stummelähnlicher Fortsatz in die Chondroepiphyse hinein, der radialwärts am weitesten von der Oberfläche des Knorpels entfernt bleibt, dieselbe aber auch ulnarwärts nicht erreicht. Im achten Jahre ragt die Diaphyse mittelst dieses Fortsatzes bis in die Nähe der Articulationsfläche; an der radialen Seite bleibt zwischen dem Fortsatz und dem entsprechenden Theil der Endfläche der Diaphyse eine dünne Lage Knorpel lange Zeit von der Articulation ausgeschlossen, die noch in zwölften Jahre 0·75 mm. mächtig ist. Sagittale Schnitte, welche etwas radialwärts von der Mitte des Knochens angelegt sind, gewähren also um diese Zeit das Bild einer selbständigen Epiphyse, während weiter ulnarwärts die Knochensubstanz des Mittelstücks und des Köpfchens continuirlich zusammenhängen. Vom zwölften Jahre an ossificirt die Zwischenknorpelscheibe langsam von der Tiefe gegen die Oberfläche; vor vollendete Ossification macerirte Knochen zeigen eine mehr oder weniger tiefe Furche zwischen Köpfchen und Körper an der radialen Seite, die als eine unvollständig verwachsene Epiphysengrenze gedeutet worden sein mag."

It seems possible that in this distal epiphysis we may have a structure capable of taking an independent development, and thus of giving rise to a supernumerary phalanx, which in this case would be the first. This hypothesis can only be put forward in a tentative manner, and, indeed, the whole question requires the further examination of suitable material, not always easy to obtain, for its complete elucidation. It may reasonably be objected that such a hypothesis leaves the question of the proximal epiphysis of the metacarpal unsettled, but it should not be forgotten that Thomson has described the occasional presence of indications of a similar epiphysis in the metacarpal bone of the index finger.

III. *Relation to the præpollex question.*

I do not intend entering at any length into this question, because I hope to do so in a paper upon which I am now engaged, and in which I propose to deal fully with the subject of polydactylism, but there are a few points which it may be

convenient to allude to now in connection with the present subject. Professor Bardeleben has brought forward much evidence to show that the typical manus and pes are heptadactylous, and that rudiments of the first (præpollex) and the seventh (postminimus) digits exist in a wide range of animals; and this view, whilst disputed by some, has received the support of other writers. I think that his theory receives a certain amount of support from the condition with which I have been dealing. It is certainly suggestive that the presence of Bardeleben's præpollex in the human manus should be accompanied by an assumption of the trimerous digital condition by the next member, viz., the normal pollex. There remain in this case the other two conditions, in which the three-phalanged pollex is met with, to be explained. With regard to those cases where the trimerous pollex replaces the normal thumb, they, I think, need not be considered in this connection, since no element of polydactylism enters into the question. But the other and rarer cases where the trimerous digit is radially placed, and is separated from the index by a dimerous pollex, are more difficult to explain. Perhaps a solution of the difficulty may be found in comparing the condition with the well-known cases where a normally trimerous digit in the centre of the series is dimerous, a state of affairs which may extend to more than one finger.

I venture to offer the following conclusions:—

- (1) That the three-phalanged pollex, when existing in a pentadactylous manus, is not an example of duplication of ordinary digit, but is a true thumb.
- (2) That the musculature shows that where there is an additional digit on the radial side, it and the digit next to the index, both partake of the nature of thumbs, and may be looked upon as the first and second digits of a hexadactylous, or, perhaps, as in Rüdinger's case, of a heptadactylous manus.
- (3) That the missing segment of the normal thumb is the proximal phalanx, and that it is represented by the distal epiphysis of the metacarpal bone.

- (4) That the combination of a supernumerary pollex with a trimerous digit separating it from the index lends a certain amount of support to Bardeleben's view as to the nature of the typical manus.
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EXPLANATION OF PLATE II.

- Fig. 1. Left hand—dorsal aspect.
Fig. 2. „ „ —palmar „
Fig. 3. Right „ —dorsal „
Fig. 4. „ „ —palmar „

**A CASE OF TRANSPOSITION OF THE THORACIC AND ABDOMINAL VISCERA WITH CONGENITAL MALFORMATION OF THE HEART AND CERTAIN ABNORMALITIES OF THE ARTERIAL AND VENOUS SYSTEMS.¹ By T. WARDROP GRIFFITH, M.D.,
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THE following case is worthy of detailed anatomical description, on account of the remarkable combination of so many structural anomalies:—

T. C., a male child aged 6 weeks, was brought to my out-patient department on September 22nd, 1890. The condition complained of was that of cyanosis, and his mother stated that this had been present from birth. The cyanosis varied very much in intensity, being sometimes very marked, and being temporarily increased by coughing or crying. He had had convulsions at birth, and had suffered more or less from cough ever since.

On examination the cardiac impulse and dulness were readily made out to the right of the sternum, while no impulse nor any dulness was perceptible on the left side. The heart sounds were much louder to the right than to the left of the sternum: no bruit was made out anywhere. A good resonant note was made out all over the area of the lungs: there was no evidence of fluid in the pleura. The liver dulness was absent from the right side, where the lung resonance and the tympanitic note of the hollow abdominal viscera were continuous with one another. The liver dulness was made out on the left side, and was apparently of normal extent, and the organ could be made out by palpation below the costal margin. The existence of the spleen could not be made out on either side by palpation or percussion. The right testicle was very slightly but undoubtedly lower than the left.

This child was the youngest of eleven. The mother stated that during the pregnancy she had suffered from palpitation, but this she did not mention until, from my frequent examinations, and my remarks on the case, she had grasped the fact that the child had some abnormal condition of the heart. The mother had had one miscarriage at the sixth month: one child, born early in the eighth month, died at the age of seven weeks of "a decline:" the child next in age to the patient was born at the full time, but lived only a few minutes. The father, mother, and all the brothers and sisters are right-handed.

¹ Communicated to the Anatomical Society, May 1891.

The patient is said frequently to twitch with his left hand, but on the many occasions I saw him I did not notice this.

The child remained constantly under my observation till its death on February 1st, 1891. During all that time it was deeply cyanosed. The same physical signs were frequently made out, but on the 13th of October I thought I made out a faint systolic bruit over the middle of the precordial area.

The general nutrition of the child was fairly good; there was no clubbing of the fingers or toes, nor were they unduly cold. On the 2nd of October Dr Lloyd Jones kindly examined the blood, and found the specific gravity was 1064.

About three weeks before its death the child began with an attack of chicken-pox, which passed through a natural course. The child was never so well after; it suffered from cough and was always more cyanosed than formerly. Death was gradual, and is said to have been preceded by jerking of the right leg and arm, and of the right side of the face.

The patient was shown at the December meeting of the Leeds and West Riding Medico-Chirurgical Society, and shortly after this I wrote out the case for publication. The subjoined paragraphs, constituting as they do without alteration my "remarks" appended to the clinical report, give the view I entertained of the case.

"There can, I think, be no doubt that a communication exists between the two sides of the heart, or between the aorta and pulmonary artery. The commonest auscultatory sign of a communication between the two sides of the heart, or at least of a patent foramen ovale, is a systolic bruit with its maximum at the base, due to obstruction at the pulmonary orifice, a condition which will prevent the closure of the foramen by determining a high blood-pressure in the right side of the heart. This physical sign was not present in the case.

"The signs of transposition were very distinct. When the signs point to transposition of the heart alone, one must carefully eliminate all sources of fallacy, such as fluid in the pleura, collapse of the lung, or deformity of the chest; and, especially when patent foramen ovale is present, one must be careful not to mistake hypertrophy of the right ventricle from pulmonary obstruction, for actual transposition.

"In this case, however, the absence of such sources of fallacy, and the altered position of the liver, leaves no room for doubt.

"Whether the transposition of the viscera, and the condition giving rise to the cyanosis co-exist in my patient otherwise than as a coincidence I cannot definitely say. Cases of cyanosis, from malformation of the heart, are not so uncommon as to render their occurring in those the subjects of transposition very unlikely, but the absence of a systolic pulmonary bruit is somewhat against this view, and makes me inclined to think there may be some anomaly in the development of the aortic bulb septum."

The *post-mortem* examination was made twenty-eight hours after death. I was assisted in making it by Mr J. W. Haigh,

to whom also I am indebted for the sketches in illustration of this paper.

The autopsy revealed essentially two conditions: firstly a transposition of the thoracic and abdominal viscera, and secondly a series of remarkable abnormalities, chiefly in the vascular arrangements. These I purpose describing together and discussing the various points of interest as I proceed.

The body was well nourished, rigor mortis was not present; there were no undue signs of decomposition.

On opening the abdomen, the notch in the anterior border of the liver was found to the left of the middle line, and the left side of the falciform ligament was directed obliquely upwards. The liver not only lay chiefly in the left side of the abdomen, but was transposed as to its details, the left lobe having the secondary lobes on its under surface. To the vascular and peritoneal relations of the liver which are of much interest, I shall return later.

The stomach was found on the right side with the pylorus directed to the left, and, as would be anticipated from a consideration of its development, the right vagus nerve was distributed on the anterior and the left on the posterior surface.

The spleen lay on the right hand side of the stomach, and was peculiarly divided into two by a furrow running vertically along its convex aspect, and a small rounded nodule of spleen-like structure (*spleniculus*) was found close to its lower end.

The small intestine presented no anomaly beyond the transposition; but the cæcum, which occupied the left iliac fossa, and the ascending colon, were enclosed within the layers of the mesentery, and could be lifted out of the abdomen, leaving the posterior wall from the diaphragm down to the left iliac fossa empty and covered with peritoneum. This anomaly is of course not a very uncommon one. I have seen two other examples of it during the last three years. The cæcum was cone-shaped, and the vermiform appendix, which had a short mesentery, was continued from its apex.

The left kidney was cystic and small, and had no true secreting tissue; the right organ was decidedly large and was normal in structure.

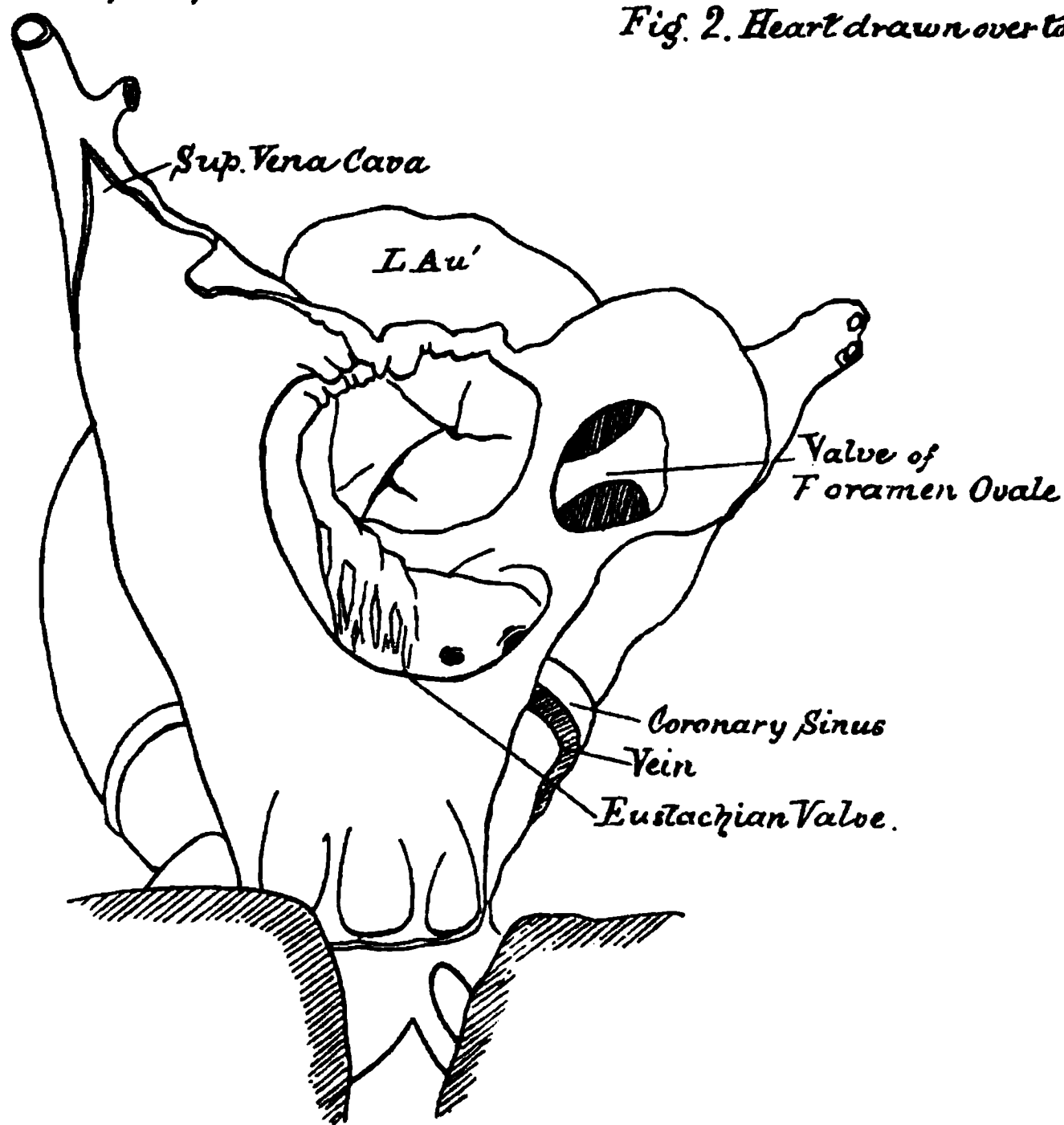
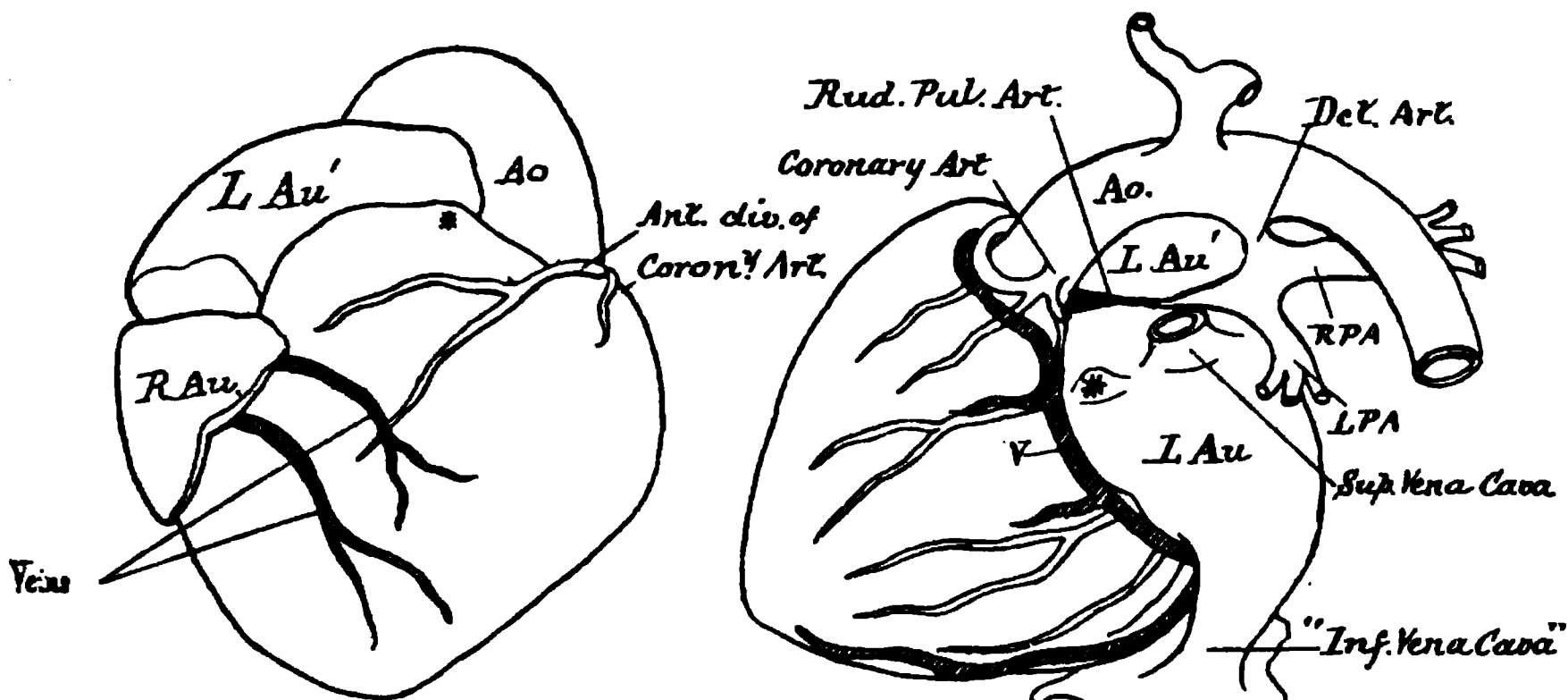
On opening the thorax the pericardial sac was found lying

well over to the right side. It was prominent, so that with the usual collapse of the lungs incidental to opening the chest the lower lobe of the right side could not be seen without disturbing the heart. There was a small amount of clear fluid in the pericardial sac.

The heart was transposed, its apex pointing to the right, and the systemic auricle was on the left side, while the vestigeal fold of Marshall was made out on the right. But besides the general transposition, there were found to be many abnormalities of development which required very careful looking into. I therefore injected the heart and great vessels with gelatine and carmine, which enabled me to make out the external configuration of the heart and the relations of the vessels. This was done from the superior vena cava, and the injection readily found its way into all the cavities of the heart and the great vessels, as well as into the cardiac veins and the coronary arteries. This injection was subsequently removed to admit of an examination of the interior of the heart.

We will begin with a general conception of transposition of the heart as a whole and of its various parts, and of transposition of the main vessels, as if the entire system were seen in a mirror.

On drawing the heart over to the right, the left auricle was well exposed to view (fig. 2). It received from above the superior vena cava—a left cava of course—and from below a large vessel coming up through the central tendon of the diaphragm, and which I refer to at present as the inferior cava. On the anterior surface of the auricle there was a small convexity or boss which at first I took for the auricular appendix (fig. 2 *), but further examination revealed a long process projecting to the right, behind the aorta and rudimentary pulmonary artery, and coming into full view from the front, pretty much in the normal position of the right auricle (figs. 2 and 1, *L. Au'*). I shall have something more to say of this presently, but now will simply state that I regard it as the auricular process proper and the boss as a chance dilatation. This auricle was opened from behind and the left by an incision from the inferior to the superior vena cava and by a transverse incision from this along to the appendix (fig. 3). The cavity was large, much larger



it will be seen than the right auricle ; its posterior and left sides were smooth, but the anterior surface and auricle presented many trabeculæ and well-marked muscoli pectinati. There was an abrupt transition from the smooth wall of the inferior cava to the auricular wall, and here a very faint fringe probably indicated the existence of the Eustachian valve. The fossa ovalis was floored by an imperfect septum, which left an upper and lower space, each bounded by the crescentic margin of the septum. Some of the coronary veins described below opened by a common orifice between the inferior cava and the fossa ovalis.

The right auricle received the pulmonary veins, which were of fair size : its auricular process extended forward under the left process and was seen from the front (fig 1.): the cavity was much smaller than that of the left side.

Each of these two cavities opened with a common ventricle, which constituted by far the greater part of the heart as seen from the front (fig. 1). Passing from the left side of the base of this ventricle was the aorta, while just to the right of this was a very slight flattened elevation exactly in the position where one would, making allowance for the transposition, have expected to find the pulmonary artery (fig. 1 *).

On opening the ventricle the cavity was found to be large and irregular, with walls of moderately uniform thickness, provided with the usual arrangement of columnæ carneæ (fig. 4). This was imperfectly cut up into two by a septum, which started below and to the left of the apex and passed upwards and to the right, extending up along the anterior and posterior walls of the ventricle, but having a crescentic, fleshy, free upper margin, so that when the parts were replaced *in situ* an opening large enough to let the handle of a scalpel pass through existed. The septum at its attachment to the ventricular wall was about $\frac{3}{4}$ -inch thick, it then diminished in thickness, and its margin measured about $\frac{1}{2}$ -inch and was rounded. Partly filling up the gap was the septal flap of the left auriculo-ventricular valve.

It is thus seen that the right ventricle formed the whole of the apex, and yet was much the smaller. Opening into this was the right auriculo-ventricular opening bounded by a bicuspid valve.

The left ventricle was much the larger : opening into this, to the right hand side of the base, was the opening from the left

auricle. The ventricular cavity extended upwards to the left, and in front of this, forming a "conus" leading to the aortic opening, which was provided with normal semilunar valves. There was no connection between the aortic semilunars and the auriculo-ventricular valves. Those of the right side were, of course, far away, and those of the left were separated from them by a thick muscular projection.

The auriculo-ventricular valves were continuous with one another by the septal flap of the left and the antero-left flap of the right; at the point of junction they were puckered, and were joined from above by the auricular septum. The right valve had two flaps, an antero-left and a postero-right, with papillary muscles arising from the ventricular walls opposite the commissures. The left valve had three flaps, which were arranged as follows (the numbers refer to fig. 4):—

1. One separating the auriculo-ventricular opening from that part of the ventricle corresponding to the flattened elevation and therefore to that part of the ventricle from which the pulmonary artery, if present, would have arisen. This corresponded to the left or upper anterior flap of normal anatomy.
2. A second, lower down, separating the auriculo-ventricular aperture from the aortic and corresponding to the right or lower anterior flap.
3. A third or septal. This was large and attached at its base as already said to the antero-left flap of the bicuspid valve. It corresponded to the septal or posterior flap of normal anatomy.

That the above represented the true homologies of the flaps was proved by a consideration of the destination of the cordæ tendineæ of the groups of papillary muscles. Thus to the contiguous margins of 1 and 2 cordæ came from the anterior group of muscles (*pa*), to the contiguous margins of 2 and 3 from the posterior (*pp*), and to the contiguous margins of 3 and 1 directly from the upper part of the septum just in front of the opening.

The aorta, arising, as already said, from the upper and left side of the ventricle, passed upwards and arched over the root of the right lung, and then descended slightly to the right

of the vertebral column. Here everything seemed to be symmetrically reversed, the right recurrent laryngeal nerve hooking round the arch of the aorta. As the aorta was the only vessel leading out of the ventricle, it was not at first sight apparent how the lungs got their blood-supply, but it was found that the two pulmonary arteries were supplied by a patent ductus arteriosus (fig. 2). This passed from the aorta downwards and backwards, and thus the acute angle it formed with that vessel was distal. It almost at once opened into a trunk which passed in both directions, the part to the right dividing, after a course of half an inch, into branches for the right lung, while that to the left was joined after a course of half an inch by the partially obliterated pulmonary artery, and then passing along with a slight change of direction for half an inch divided into branches for the left lung. It will thus be seen that the ductus arteriosus opened into the right pulmonary artery. The main stem of the pulmonary artery was represented by a fibrous cord, closely adherent to the posterior and right aspect of the aorta, and which on careful dissection could be traced down to the flattened elevation of the ventricle, formerly mentioned as lying to the right of the aorta. It became pervious about three-quarters of an inch from its junction with the two pulmonary arteries, expanding in a fusiform manner till its calibre was equal to that of either of these vessels.

The relation of the left auricle to this partially obliterated trunk is worthy of close attention. It will be recollected that a large part of this was, as it were, dislocated behind the aorta and rudimentary pulmonary artery, and it is difficult to avoid the conviction that it may, by pressure, have prevented the development of the proximal part of the fifth right branchial arch, and thus led to an almost total absence of the main stem of the pulmonary artery.

The lungs were further supplied with blood by the bronchial arteries, which were considerably enlarged.

The relations of the above abnormalities in the main vessels will be rendered clear by figures 5 and 6. Fig. 5 is adapted from Schäfer's modification of Rathke's diagram, and shows transposition without further abnormality. Fig. 6 shows what existed in my case.

*Fig. 4. Ventricle opened by incision along
left margin.*



Fig. 5.



Fig. 6

The cyanosis is readily accounted for. The whole of the blood did not pass through the lungs; they simply took their chance with any other part of the body, and the small amount of pure blood which was returned from the lungs was freely mixed with the impure systemic blood in the common ventricle. In fact, the purification of the blood was effected by a small quantity being diverted from the main stream, arterialised, and turned into the main stream again.

The arrangement of the coronary arteries and cardiac veins is worthy of attention. There was only one coronary artery, and it arose from the aorta opposite the postero-left flap (fig. 2). Its origin was low, so that it was covered entirely by the flap when that was placed in apposition with the wall of the vessel. This divided at once into two main divisions.

1. The one gave a few twigs down the left margin of the ventricle, and then passed round the origin of the aorta to the right and front; here it divided into two branches, one going to the stump of the conus arteriosus, and the other passing obliquely down the front of the ventricle, lying at first on the front of the left ventricle, and then on the front of the septum, and being here in relation with the beginning of the great cardiac vein (figs. 2 and 1).
2. The other main division passed backwards and downwards between the left auricle and ventricle, giving twigs chiefly to the latter, and then divided into two, of which one went down the back of the septum with a vein, and the other passed on between the right auricle and ventricle with the coronary sinus, and ended in small twigs passing down the right margin of the heart.

The coronary sinus (fig. 3) lay in the posterior auriculo-ventricular furrow on the right side, and opened into the left auricle between its ventricular opening and the fossa ovalis. Opening along with this was another vein which lay below it in the same furrow, and came from the right margin of the heart. Starting at the apex were two veins which passed up along the anterior part of the septum into the depression between the two auricular processes (fig. 1); the left hand one turned sharply to the right and was joined by the other and passed round between

the right auricle and ventricle, and was continuous with the coronary sinus. Joining the sinus from above and the right side was a small vein, pervious and corresponding to Marshall's vein. Its distal connexion was not made out. One vein came up the posterior part of the septum and ended in the auricle close to the sinus. Another vein, seen in fig. 2, originating apparently on the left margin of the heart, passed with the main anterior branch and then with the main posterior, and ended close to the sinus in the auricle. Thus the sinus and its companion vein opened together, and the two others separate, but they all opened in a common depression. There was no appearance of any valves.

VASCULAR RELATIONS OF THE LIVER (fig. 7).

The portal vein passed up to the left extremity of the transverse fissure of the liver, and divided into right and left

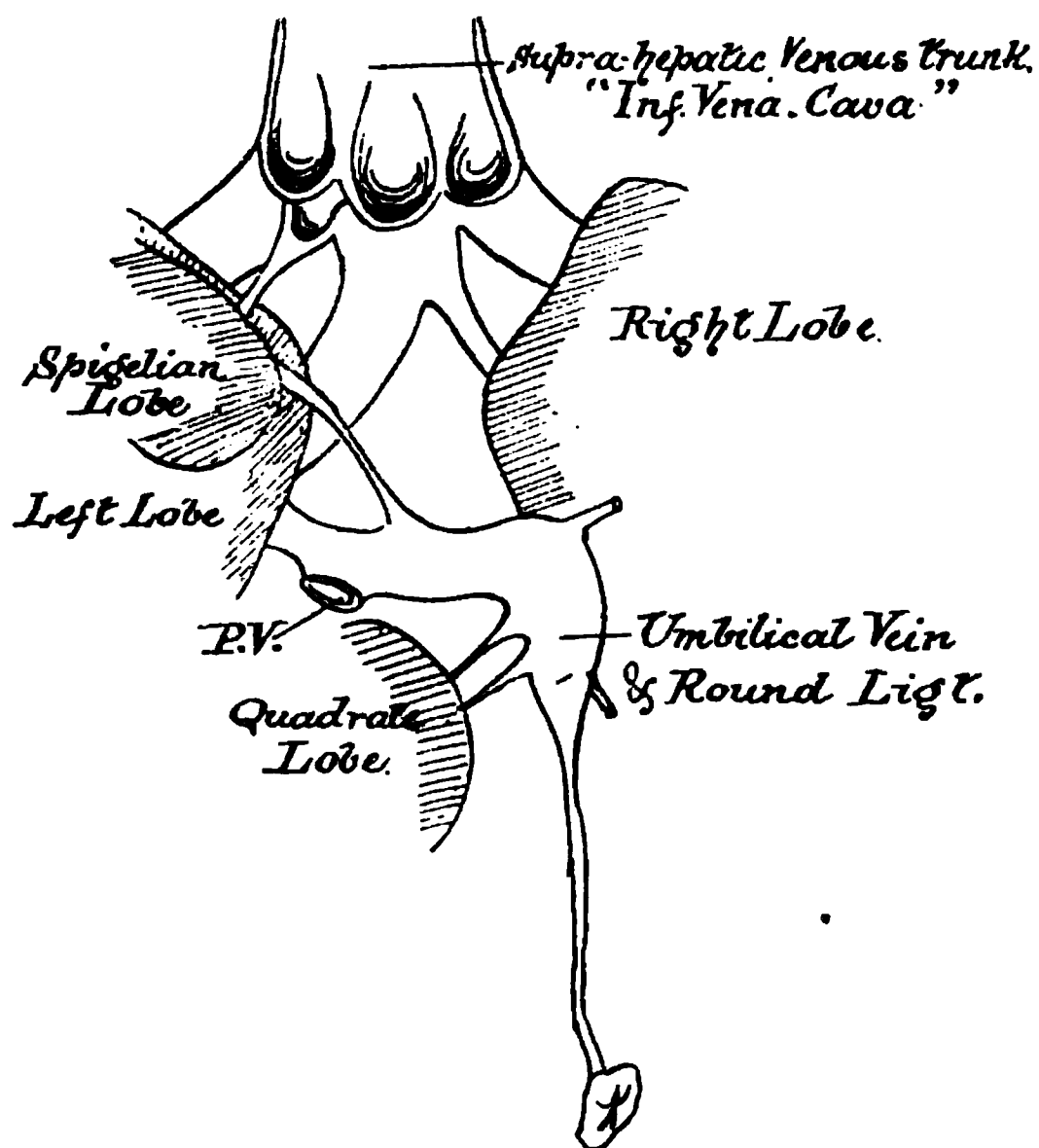


Fig. 7. Vascular relations of Liver.

branches. The former entered at once into the left lobe, and the latter passed along the transverse fissure, and after giving

off a branch to the Spigelian lobe was joined from the front by the remains of the umbilical vein. This was widely patent for about an inch, and here it gave off two branches to the quadrate lobe and two branches to the right lobe, one of these coming from its point of junction with the right portal vein.

Careful dissection failed to reveal any remnant of the ductus venosus. This is interesting when taken in connection with the recent investigation of His on the development of the veins. Until lately the ductus venosus has been regarded as that portion of the common trunk of the vitelline and umbilical veins between the venæ hepaticæ advehentes and the venæ hepaticæ revehentes. The investigations of His, on the other hand, show that the direct communication of the umbilical and vitelline veins with the sinus venosus is *completely* interrupted by the development of vascular networks, that there is therefore a time during which all the blood passes through the capillaries of the liver, and that the ductus venosus is a trunk of later development. From the complete absence of any trace of the ductus venosus in my case, I am disposed to think this later development had not taken place, and that up till the end of foetal life, all the blood from the placenta and portal vein must have passed through the capillaries of the liver.

Perhaps the most striking point in the whole case was the absence of the inferior vena cava, for the vessel I have referred to under that name as piercing the central tendon of the diaphragm, and, ending in the systemic auricle, was found to be formed solely by the junction of the hepatic veins. These left the liver at the upper part of its posterior surface, and were four in number; one came from the longitudinal fissure, and was formed by the union of a large branch from the left lobe and another from the right; one small branch came from the Spigelian lobe, and the two remaining ones from the right and left lobes respectively.

The peritoneal investment of the liver was much more complete than usual, indeed it was only the presence of the hepatic veins that prevented the upper and lower layers of the coronary ligament coming in contact all the way along, and immediately to the right and left of these the two layers did come into contact, forming extensive triangular folds, which were really enlarged right and left lateral ligaments.

Unfortunately a complete dissection of the azygos veins was not made, but during the examination it was noticed that they were all extraordinarily enlarged, the left one especially so, and this, after being joined by a large superior intercostal, arched forward over the root of the left lung, and ended in the superior vena cava, which lay on the left side. In this way, therefore, the blood from the lower limbs was conveyed to the heart.

In the *Archives de Physiologie* for July 1888, Carpentier and Bertaux give an account of a case in which there was absence of the inferior vena cava, with compensatory enlargement of the great azygos vein, and in which the efferent vessels from the liver formed a supra-hepatic trunk, ending directly in the right auricle of the heart. They give a most interesting account of the anomaly from the point of view of its development, and show that Cruveilhier described a case exactly similar without recognising its nature, as he took the enlarged azygos vein for a vena cava in an abnormal position.

ON THE FOSSÆ ROUND THE CÆCUM, AND THE
POSITION OF THE VERMIFORM APPENDIX,
WITH SPECIAL REFERENCE TO RETRO-PERI-
TONEAL HERNIA. By C. B. LOCKWOOD, F.R.C.S.,
and H. D. ROLLESTON, M.B.

(Communicated to the Anatomical Society of Great Britain and Ireland.)

SOME time ago our attention was attracted to the occasional concealment of the vermiform appendix within the pouches which surround the cæcum.¹ The search for more examples of this variety of retro-peritoneal hernia has been continued, and the results are given in this communication. The success which has attended our efforts has been considerable, and we are now able to refer to more than twenty-three fresh examples. Further, we have taken the opportunity of ascertaining and noting the other, and more usual, positions which the vermiform appendix may occupy. The last branch of our subject has received a great deal of attention, and does not require so much discussion. But retro-peritoneal hernia of the vermiform appendix has been singularly overlooked, and we propose to refer in detail to the fresh examples which we have found.

The whole subject of retro-peritoneal hernia of the vermiform appendix is inextricably connected with that of the anatomy of the various peritoneal fossæ around the cæcum. Therefore it will be necessary, as we proceed, to give an account of these pouches.

The more recent writings² show that there is great difference of opinion as to their anatomy. We have met with two of first rate importance, viz., the *ileo-cæcal* fossa, which is situated at the angle between the ileum and cæcum, and the *subcæcal*, the mouth of which is underneath the cæcum, and which runs

¹ *Hunterian Lectures on Hernia*, by C. B. Lockwood, Lond. 1889, p. 83 *et seq.* Also "Retro-peritoneal Hernia of the Vermiform Appendix," by the same author, *Trans. Path. Soc. Lond.*, vol. xli., 1890, p. 118.

² Jonnesco, *Hernies Internes Rétro-Peritonéales*, Paris, 1890, p. 104 *et seq.*

upwards beneath the right colon. These fossæ, which will be described presently, are almost constant. Their existence is quite independent of the presence or absence of an appendix, or of its mesentery. And, here, it may be said, that we do not believe that the vermiform appendix is ever absent, except as the result of disease. The instances in which absence has been assumed¹ are capable of another explanation. As will be seen later, the appendix is often hidden away in either the ileo-cæcal or subcæcal pouch. Further, the entrances of either of these pouches may be occluded, so that nothing but a careful dissection would reveal the presence of either the pouch or of its contents.

Observers have always determined the presence of these pouches by looking for the entrance into them, but it is evident that the fact that the entrance may not exist throws great doubt upon any observations founded upon that method.

In connection with this question it is interesting to note that Schott² has given two instances of cysts near the ileo-cæcal junction, which he attributes to closure of the mouths of the ileo-cæcal fossæ. One of these cysts was found by Widerhofer in a child of 18 months; it was as large as a walnut, and contained colloid contents. The other was found in an adult, and was as large as an apple, tense, with thin walls, and clean serous contents. It might also be found that cysts occurred in the situations of the other peritoneal pouches, viz., of the intersigmoid and jejuno-duodenal.

That retro-peritoneal hernia of the vermiform appendix has been almost entirely overlooked and its importance ignored, is shown by a reference to the writings of others. Mr Treves, who examined the cæcal region in one hundred bodies, does not mention it.³ Jonnesco, the latest writer⁴ upon the subject, merely refers to Tuffier's⁵ casual remark that he had found fossæ behind the cæcum which often lodged in the vermiform appendix. Our best text-books are silent upon the

¹ "On the Surgical Anatomy of the Vermiform Appendix," by John Ferguson, *Amer. Jour. Med. Sci.*, vol. ci., p. 61.

² *Beiträge zur Anatomie der Fossa Ilio-Cæcalis. Wochenblatt der Zeitschrift der K.K. Gesellschaft der Aerzte in Wien*, 1862, pp. 345-347.

³ *Hunterian Lectures on the Anatomy of the Intestinal Canal and Peritoneum in Man*, by Frederick Treves, Lond. 1885, p. 46 et seq.

⁴ *Loc. cit.*, p. 115.

⁵ "Étude sur le Cæcum," *Archives Générales de Médecine*, 1887, p. 652.

question, and also¹ the writings of Luschka, Langer,² or Bardeleben.³ Nor does Ferguson allude to it although he made a special examination of the vermiform appendix in two hundred bodies.⁴ However, he remarks that it was in seventy-seven instances so situated behind the cæcum that a perforation of it would have opened into the subperitoneal cellular tissue, and this exemplifies the importance of our subject. As we proceed, it will be seen that the recognition of this variety of retro-peritoneal hernia affords a ready explanation of the course which the pus has been known to take in cases of perforation of the appendix, especially those in which it travels upwards behind the right colon to the right kidney, and onwards, perhaps, as far as the diaphragm and right lung and pleura.⁵ Further, as our statistics show, the appendix is so often concealed in retro-peritoneal fossæ, that surgeons ought certainly to be familiar with the fact. We have heard of more than one instance in which operators have failed to discover the appendix, and have therefore closed the abdomen after coming to the conclusion that it was absent.

In concluding this brief reference to the literature, we note that Mr L. A. Dunn⁶ showed a specimen at the Pathological Society of London in which the vermiform appendix lay in a fossa behind the cæcum, and Dr Mott⁷ one in which it lay in the fossa iliaca subfascialis. Both of these references are exceedingly brief.

Ileo-colic Fossa.—By this name we wish to designate a peritoneal fossa, which is found at the junction of the ileum and colon (figs. 1 and 3). As those intestines lie in their natural position, they form an angle which has the ascending colon for its outer boundary and the ileum for its lower, and the mesentery for its floor. Very often a fold of peritoneum roofs in this angle, and it thus becomes a fossa, the mouth of which looks upwards

¹ "Ueber die Peritoneale umhüllung des Blinddarmes und ueber die Fossa Ilio-Cæcalis," Luschka, *Virchow's Archiv für Path. Anatomie*, vol. xxi. pp. 285–288.

² *Die Peritoneal Taschen am Cæcum. Wochenblatt der Zeitschrift der K.K. Gesellschaft der Aerzte*, Langer, 1862, pp. 129–131.

³ "Ueber die Lage des Blinddarmes beim Menschen," *Virchow's Archiv für Path. Anatomie*, vol. ii., 1849, p. 288.

⁴ "The Surgical Anatomy of the Vermiform Appendix," *The Amer. Jour. Med. Sci.*, vol. ci., No. 1, p. 61.

⁵ See A. Fraenkel, "Ueber die Folgen des Perforation des Processus Vermiformis und deren Behandlung," *Deutsche Med. Wochenschrift*, Jan. 22, 1891, p. 137 *et seq.* Also Treves, *Brit. Med. Jour.*, Nov. 9, 1889, p. 1030.

⁶ "Retro-cæcal Hernia of the Appendix Cæci," *Trans. Path. Soc.*, vol. xl., 1889, p. 114.

⁷ "Two Anomalous Vermiform Appendices," *Trans. Path. Soc.*, vol. xl., 1889, p. 105.

and towards the left, whilst its apex is at the junction of the ileum and cæcum (*vide* figs. 1 and 3).

The floor of the ileo-colic fossa is formed by the mesentery, and sometimes by a portion of the ileum. The fold of peritoneum



FIG. 1.—The Ileo-colic Fossa; the arrow marks the fossa. C, cæcum; I, ileum; I.C.F., ileo-colic fold.

which roofs it in carries a branch (arteria ileo-cæcalis anterior) of the ileo-colic artery to the front part of the cæcum, crossing the ileum in its course. This fold has had various names given to it. Treves and Tuffier call it the superior ileo-cæcal fold; referring, perhaps, to its vascular contents. Jonnesco, keeping its beginning and end in view, names it the mesenterico-cæcal. Inasmuch as it seldom reaches the cæcum, and to avoid confusing it with another ileo-cæcal fold, which will be mentioned presently, we shall in future call it the ileo-colic fold after the fossa which lies beneath it. This ileo-colic fold varies, and it may be either absent, or run over the front of the ileum along the colon as far as the cæcum. Of course the ileo-colic

fossa varies in depth and extent according to the width of the fold. The ileo-colic fold is sometimes laden with fat; and at others fringed with appendices epiploicæ.

The fossa which we have termed the ileo-colic has been called by other names. Waldeyer, Hartmann, Treves, and Tuffier call it the superior ileo-cæcal fossa; Jonnesco merely calls it the ileo-cæcal.¹ However, the fossa has for its main boundaries the ileum and colon, and is quite independent of the cæcum. Therefore, we prefer to call it the ileo-colic fossa lest it be thought that it has anything to do with the cæcum. Doubtless confusion has arisen from an imperfect definition of the extent of the cæcum. As one of us has said elsewhere² "the cæcum is that part of the large intestine which is situated below the entrance of the ileum, and would, therefore, be marked off from the large intestine by a line drawn across the right colon at right angles to its axis, and in the same level as the lower margin of the ileum. This definition accords with the developmental history of the cæcum, because it originates as a diverticulum from the side of the rudimentary alimentary canal, and under normal circumstances this outgrowth is entirely covered with a layer of serous membrane, which it retains throughout the life of the individual."

We have not as yet met with any cases of hernia into the ileo-colic fossa, and we have also observed that the presence of this pouch is comparatively rare.

The Ileo-cæcal Fossa.—This fossa is situated behind the angle of junction of the ileum and cæcum, which have both to be lifted up to see its mouth (*vide* fig. 2). The fossa itself runs a varying distance upwards behind the ileo-colic junction and parallel to the ascending colon. It is bounded to the right by the mesentery of the ascending colon, and on the left by *the* mesentery. The fossa in the accompanying figure was almost 3 inches long, and would easily admit the finger or a loop of intestine. Sometimes the ileo-cæcal fossa reaches half way up the ascending colon beyond the crest of the ilium, and ends close to the kidney and duodenum. Thus, when the appendix suppurates whilst lying in such a fossa, the resulting abscess may be mistaken for one connected with the kidney. According to this description, which is founded upon the examination of many specimens, the ileo-cæcal fossa is in its typical state comparatively simple and quite independent of the vermiform

¹ *Loc. cit.*, p. 116 *et seq.*

² Lockwood, *Lectures on Hernia*, p. 139.

appendix or its mesentery, or of any other peritoneal folds, except the mesentery of the ascending colon and *the* mesentery.

Origin of the Ileo-cæcal Fossa.—The ileo-cæcal fossa is developed during the descent of the cæcum and end of the ileum into the iliac fossa. It is well known that the cæcum is at one time situated beneath the liver, and, together with the colon, is carried upon the same mesentery as the rest of the intestines. From its high position the cæcum, together with the end of the ileum, the mesentery, and vermiform appendix, descends into the

FIG. 2.—The Ileo-cæcal Fossa, to illustrate Retro-peritoneal Hernia of the Vermiform Appendix into the Ileo-cæcal Fossa; the arrow marks the fossa. I, ileum; C, cæcum.

iliac fossa; its progress being assisted by the gubernaculum. The gubernaculum does this by means of an accessory band of muscular fibres, which it sends upwards beyond the ovary or testis in the plica vascularis. The latter fold is the upper part of the mesorchium or mesovarium, and has been described by one of us¹ under the name of plica vascularis; because it contains the spermatic or ovarian vessels. The plica vascularis ends above upon either the vermiform appendix, the mesentery, the

¹ "The Morbid Anatomy and Pathology of Encysted and Infantile Hernia," by C. B. Lockwood, *Medico Chirurgical Trans.*, vol. lxi. p. 508.

cæcum, or ileum. As it assists in pulling those organs towards the iliac fossa, the peritoneum beneath the mesentery descends unequally, and the part near the ileo-cæcal junction remains behind. Hence, by the time the cæcum and right colon have assumed their permanent position, a recess has been created, which is the ileo-cæcal fossa. Another factor in the process is the substitution of the permanent ascending mesocolon for the original one, which, as we have already said, is part of the mesentery.

The reason for the incomplete descent of the peritoneum which forms the ileo-cæcal fossa is obscure. The explanation probably turns upon the action of the blood-vessels and suspensory muscle of the mesentery in restraining the movements of the peritoneum at the angle between the ileum and colon, this being the portion of serous membrane which, by its occasional incomplete descent, forms the ileo-cæcal fossa.

The anatomy of the ileo-cæcal fossa is seldom as simple as we have described. It is usually complicated by two folds of peritoneum, one of which is the mesentery of the vermiform appendix, the other a fold of doubtful origin, and usually called the plica ileo-cæcalis.

The Meso-appendix.—The mesentery of the vermiform appendix is fairly constant. It consists of two layers of peritoneum, between which the vessels, lymphatics, and nerves of the appendix run. Its usual characters are shown in the accompanying sketch (fig. 3). Above it has a base which often springs from the under layer of the mesentery; below, its layers are reflected round the appendix; towards the right, it ends at the ileo-cæcal angle; whilst, towards the left, it has a sharp, free edge which contains the appendicular vessels and some fat. When the cæcum, ileum, and appendix are disposed so as to display the meso-appendix, its plane is in many cases at right angles to that of the mesentery, and parallel to that of the iliac fossa.

The meso-appendix seldom reaches more than half or two-thirds of the way along the appendix, and usually gives the impression of being too short, so as to cause the appendix to coil upon itself.

The meso-appendix is variable, and we have observed the

following deviations from the above account. (1) It is sometimes absent, so that the vermiform appendix is quite free in the abdomen. (2) It may be longer than usual, and reach as far as the free end of the appendix. In one of our specimens it reached as far as the end of an appendix 4 inches long. (3) It may have become obliterated by its peritoneum having been spread out in the iliac fossa by the traction of the gubernaculum. The

FIG. 3.—The Folds about the Cæcum. C, cæcum; C.A., ascending colon; I, ileum; I.C., ileo-colic fold; I.C.F., ileo-cæcal fold; M, mesentery; M.A., meso-appendix. The arrow marks the superior ileo-cæcal fossa.

accompanying sketch (fig. 1) shows this variation, and it may be noted that only the cæcal end of the appendix has become bound down in the iliac fossa, and that the other end, which seldom has any mesentery, remains free. (4) The meso-appendix may be hidden away and attached within the ileo-cæcal or sub-cæcal fossa. (5) It may have a hole in it through which the small intestine has been known to herniate and become strangu-

lated.¹ (6) Its attachments vary. Often it springs from the mesentery, but it may originate from the iliac fossa or cæcum, or from both, or from the back of the colon, as in one of our specimens in which the colon of a child was floating, not having assumed its mesocolon. We need scarcely repeat that it may be attached within the ileocæcal or subcæcal fossæ.

When the meso-appendix is present it may, as in two specimens which lie before us, partition the ileo-cæcal fossa so as

FIG. 4.—The Superior and Inferior Ileo-cæcal Fossæ. C, cæcum; I, ileum; M.A., meso-appendix; M.C., meso-cæcum; M, mesentery.

to make it into two compartments—one above and the other below the meso-appendix, and called therefore, in the rest of this communication, the superior and inferior ileo-cæcal fossæ (fig. 4). Both of these subsidiary fossæ are, however, merely accidental and dependent upon the presence and position of the meso-appendix.

In the specimen delineated in fig. 4, the meso-appendix, besides being attached to the floor of the ileo-cæcal fossa, runs a

¹ See a case by T. E. Little, *Dub. Jour. Med. Sci.*, 1871, vol. lii. p. 236.

little way upon the cæcum ; but it is difficult in a drawing to show the continuity of the two parts of the fold.

The Ileo-cæcal Fold.—This fold is situated in the ileo-cæcal angle, and, although liable to considerable variation, is fairly constant. In specimens in which the folds are very well developed it lies in front of the meso-appendix (fig. 3), and consists of two layers of peritoneum, between which are some fat and muscular fibres, and arteries and veins derived from three sources, viz., from the anterior and posterior ileo-cæcal, and from the appendicular vessels ; which latter are recurrent. None of these vessels are very large, but they were easily seen in the various specimens which we injected. Therefore, we cannot agree with Mr Treves¹ in calling the ileo-cæcal fold “the bloodless fold.” Most often, however, the ileo-cæcal fold is small and comparatively non-vascular, and merely lies in the ileo-cæcal angle (figs. 2 and 5). Two of its sides are fastened on either hand to the ileum and cæcum, and the other is free and forms the upper boundary of the mouth of the ileo-cæcal fossa.

But in those cases in which the ileo-cæcal fold does not agree with this account it is still more or less triangular, with its apex at the ileo-cæcal junction and its base free, but bounding the mouth of the *superior ileo-cæcal* fossa, instead of the mouth of the *ileo-cæcal* fossa ; the latter having been subdivided by the meso-appendix (fig 3). Also, of its two sides the superior is attached to the ileum, the other to the cæcum and upper surface of the meso-appendix (fig. 3.); sometimes this attachment is to the appendix itself. When the ileo-cæcal fold has this arrangement its upper surface looks towards the general peritoneal cavity, whilst its lower surface forms the roof of the superior ileo-cæcal fossa.

In a specimen which lies before us the ileo-cæcal fold is attached to the meso-appendix so near the mesentery that the superior ileo-cæcal fossa is a long, narrow slit, lying upon the side of the ileum.

The ileo-cæcal fold is not infrequently absent, and sometimes its situation is occupied by two folds (fig. 1).

There is much difference of opinion as to the nomenclature, anatomy, and morphology of the ileo-cæcal fold, and of the superior

¹ *Loc. cit.*, p. 49.

ileo-cæcal fossa. We have already mentioned our objection to the name which Mr Treves has given to the fold, viz., "the bloodless fold." We have called it the ileo-cæcal fold in accordance with Luschka's nomenclature. Tuffier and Waldeyer have called it the superior ileo-cæcal fold. Jonnesco refers to it as the "repli iléo-appendiculaire ou antérieur," and he calls the superior ileo-cæcal fossa the "fossette ileo-appendiculaire."

As regards the origin of the ileo-cæcal fold, our investigations incline us to think with Mr Treves that it was originally developed to carry blood-vessels to the cæcum and vermiform appendix, but that it has been replaced by the meso-appendix, which affords a shorter and more convenient route. Thus the ileo-cæcal fold would correspond to, and be the fellow of, the ileo-colic fold, which, it may be remembered, also carried vessels to the cæcum and appendix; one set passing over the ileum, the other under.

When we consider the great variations which occur in the folds and fossæ around the cæcum, it is easy to understand the great divergence of opinion which prevails as to their anatomy.¹

In the course of this communication we have mentioned four peritoneal folds—viz., (1) the ileo-colic fold, which bounds the ileo-colic fossa; (2) the ileo-cæcal fold, which deepens the ileo-cæcal fossa, and sometimes bounds the superior ileo-cæcal fossa; (3) the meso-appendix, which sometimes divides the ileo-cæcal fossa into two parts, viz., the superior and inferior ileo-cæcal fossæ; and (4) the plica vascularis.

The Subcæcal Fossa.—The subcæcal fossa is situated directly beneath the cæcum, which has to be lifted up to bring it into view. It is less often present than either the ileo-colic or the ileo-cæcal fossæ. Its anatomy is comparatively simple, and not, as a rule, complicated by any peritoneal folds, except, occasionally, the plica vascularis. Its mouth is usually at the junction of the cæcum and colon, or beneath either, and it separates the layers of the mesocæcum or mesocolon (fig. 5); its fundus runs upwards behind the ascending colon, between the layers of the ascending mesocolon. The length of the subcæcal fossa varies, but we have often seen it reach as far as the crest of the ilium, or beyond.

The subcæcal fossa lies close to the ileo-cæcal fossa, and is

¹ See also Alexander Macalister "On Two Dissimilar Forms of Perityphlic Pouches," *Proceedings of the Royal Irish Academy*, July 1875. A hernia of the appendix into the subcæcal fossa is given in this paper, and a number of references.

divided from it by the left side of the mesocæcum and ascending mesocolon (fig. 5). We doubt not but that these fossæ have often been mistaken for one another; but the subcæcal fossa, it is to be noted, is not in relation with either the ileum or its mesentery. In the case of the ileo-cæcal fossa being partitioned by the meso-appendix, then the latter fold would assist in distinguishing the inferior ileo-cæcal fossa from the subcæcal in as much as it would be the left boundary of the ileo-cæcal fossa, but have no share in forming the subcæcal.



FIG. 5.—Subcæcal Fossa, shewing a hernia of vermiform appendix into it. C, cæcum; I, ileum; I.C., ileo-cæcal fold. I.C.F., ileo-cæcal fossa; the arrow points into the fossa. M, mesentery. S.C.F., subcæcal fossa.

As regards the origin of the subcæcal fossa, we have nothing to add to that which has been said already about the formation of the ileo-cæcal fossa. Like the latter, it originates during the progress of the cæcum and right colon into the iliac fossa, and it is during this event that the vermiform appendix may become herniated into it.

The subcæcal fossa has also been called the cæcal, and retro-cæcal.¹ There are some who think that it originates by a process of adhesion

¹ Jonnesco, *loc. cit.*, p. 125.

between the intestine and abdominal walls. It is said that there are sometimes two subcæcal fossæ, but we have not met with this condition.

The Positions of the Vermiform Appendix.

We now propose to describe the positions of the vermiform appendix, and at the same time refer to hernia of it into the subcæcal and ileo-cæcal fossæ. But, before doing so, it may be mentioned that the small intestines occasionally intrude themselves into those pouches.

Those who are interested in the subject will find in Jonnesco's work, to which we have repeatedly referred, a good account of cases in which the ileum has entered the superior ileo-cæcal fossa, the ileo-cæcal fossa, or the subcæcal fossa; and in some of these instances the intestine had been acutely strangulated. However, as we have met with no cases of this kind, we will proceed forthwith with the description of the position of the vermiform appendix.

The position and relations of the appendix were noted in 160 consecutive cases in which there was no manifest morbid condition of the abdominal cavity, such as peritonitis or local inflammation round the cæcum and appendix.

There were 104 male subjects and 56 female. The ages varied between 13 weeks and 81 years.

When free, that is to say, when held by nothing except the mesentery which we have just described, and when pervious, the appendix was considered to be normal.

The Normal Positions of the Vermiform Appendix.

1. In many cases the appendix is found lying under the inferior layer of the mesentery directed upwards and to the left in the direction of the spleen, a position which Mr Treves¹ considers to be its usual position.

2. Often the free appendix is found lying on the brim of the pelvis or projecting into the cavity of the pelvis, and in cases of peritonitis we have seen the appendix fixed to the right side of the pelvis, the broad ligament, or the bladder. When in

¹ *Hunterian Lectures*, Royal College of Surgeons, 1885, p. 48.

this position the appendix may, if diseased, be felt per rectum, and, as might be expected, inflammation of it has been known to cause bladder symptoms.

These two positions we have found to be the most usual for the vermiform appendix, and with a freely movable appendix it appears a matter of chance which of them is found. The appendix is easily displaced from one position to the other, so much so that we have hardly thought it possible to put it into correct statistical form.

3. With a long meso-appendix it may lie to the right of the cæcum and ascending colon, running upwards parallel to the colon, over the kidney and towards the right lobe of the liver.

4. The appendix may be found lying free over the cæcum and colon—we have recently noted this condition in a child of 5 months. This position is easily changed into that in which it lies parallel to the colon (v. 3 s.).

5. The appendix may lie perfectly free underneath the cæcum. Mr Treves¹ considers this as the commonest position for the vermiform appendix after (1); he found it in eighteen cases out of the hundred he examined. We have found it but rarely.

A pervious free vermiform appendix may, we consider, normally occupy any one of these five positions, though the first two are the most common.

In the 56 female subjects the normal condition was noted thirty times. In the 104 male cases it was found sixty-three times.

Appendix Free but Impervious.

In seven cases the vermiform appendix, though perfectly free and movable, was found to be impervious for its whole extent, this occurred four times in males, three times in females.

The appendix is frequently found partially impervious in old people, often for its distal third or half.

Occasionally cysts are found in connection with the appendix; thus in a woman aged 28 years the communication with the cæcum was closed, and the tube had colloid contents. Again, in a woman aged 70 years there was a calcareous mass encysted in the middle of the appendix, the lumen elsewhere being obliterated.

¹ *Loc. cit.*

ated. In a man aged 60 years there was a calcareous mass at the tip of the appendix, the rest of the lumen of the tube being obliterated. In all these the appendix was free, and there was no evidence of any inflammatory process.

*Abnormal Positions, including Retro-peritoneal Hernia
of the Appendix.*

Under this heading we shall record all the instances of the appendix which we have noticed as (1) being fixed to the peritoneum lining the abdominal walls; (2) lodged in the retro-peritoneal fossa around the cæcum; (3) lodged in fossæ, the mouths of which have become closed. Instances of this latter class have, as we have already said, been described as congenital absence of the vermiform appendix.

Now, as any peritoneal inflammation around the appendix might fix it to the peritoneum, or so bind it down as at first to simulate a hernia of the appendix into one of the fossæ described above, care has been taken to look for any evidence of inflammation, and when any doubt existed the case has been discarded.

Abnormal positions of the vermiform appendix may be considered as being caused by—

1. Abnormal deficiency of the meso-appendix, as the result of which the appendix may lie (*a*) behind the peritoneum below the cæcum, viz., in the region of the subcæcal fossa; (*b*) fixed to the under surface of the cæcum and ascending colon; (*c*) behind the peritoneum in the region which the ileo-cæcal fossa would occupy if it was present; (*d*) fixed to the peritoneum along the outer or right border of the cæcum and ascending colon.
2. The existence of the retro-peritoneal fossæ described above, into the mouths of which the free appendix may pass, and thus constitute a retro-peritoneal hernia of the appendix cæci.
3. A combination of these two factors, the appendix, owing to a deficiency of its own mesentery, being fixed to the

peritoneum forming the floor of a developed ileo-cæcal (fig. 1) or subcæcal fossæ.

The abnormal positions of the vermiform appendix may be classified as follows :—

First. The vermiform appendix being fixed to the peritoneum in the region of the subcæcal fossa when that fossa is not developed. The appendix may be wholly or partially bound down to the peritoneum; for example, the proximal half or two-thirds may be fixed while the distal segment is free, either with a small meso-appendix or without.

The appendix was found in this position seven times. Six times in male subjects, once in a female subject.

This position of the appendix may be easily derived from the common normal position of the appendix on or over the brim of the pelvis by the withdrawal of its meso-appendix, due, as we have already described, to the peritoneal displacement by the gubernaculum.

Second. The appendix may be adherent to the under surface of the cæcum in contact with its muscular wall, and covered by its peritoneal investment. The end of a long appendix may pierce the peritoneum and pass upwards behind the ascending colon into the loose cellular tissue around the kidney. In such cases the tip of the appendix may lie over the kidney or in relation with the right lobe of the liver. Ulceration and suppuration of the appendix in this situation may easily simulate a lumbar or nephritic abscess, or even an empyema. In some cases the appendix was fastened to the cæcum in the way we have just described, with its tip projecting for half an inch into that part of the peritoneal cavity which lies behind and to outer side of the colon.

The appendix was noted as being tied down in the above way to the posterior surface of the cæcum in nine cases. Six times in male subjects, three times in female subjects.

Third. The appendix may be found in the subcæcal fossa either free or adherent to the peritoneum lining the fossa (*vide* fig. 5).¹

The appendix was found coiled up in the subcæcal fossa twelve times. Nine times in male subjects, three times in female subjects.

If suppuration occur in connection with the vermiform appendix when lying in the subcæcal pouch, the mouth of the pouch is soon closed, and a local abscess instead of general peritonitis will result. We have seen such an abscess travel down the sheath of the psoas and present in the groin, or discharge itself into the cæcum.

Fourth. The appendix may be fixed to the peritoneum along the right border of the cæcum and ascending colon; the tip is often quite free and stands up like a crook, unprovided with a meso-appendix. This condition is easily derived from one of the normal positions of the appendix by the subtraction of its meso-appendix.

This condition was noted five times. Three times in male, twice in female subjects.

Fifth. The appendix may be fixed behind the peritoneum in the region of the ileo-cæcal fossa, that fossa not being developed (*vide* fig. 1). When long, the appendix may be adherent to and covered by the inferior layer of the mesentery. The tip of the appendix, as in the preceding positions, may be free either with or without a meso-appendix. This position is easily derived from the common normal position of the appendix by the subtraction of its meso-appendix.

This condition was found twelve times. Eight times in males, four times in females.

Sixth. The appendix may be found in the ileo-cæcal fossa (*vide* fig. 2), where it may be free, or from deficiency of

¹ For examples, *vide* Dunn, *Path. Trans.*, 1889, p. 114; Lockwood, *Hunterian Lectures*, 1889, p. 81.

the meso-appendix, may be adherent to the peritoneum forming its floor.

This variety of hernia was found nine times; five times in male subjects, and four times in female subjects.

Ulceration of the appendix within the ileo-cæcal fossa leads to a local abscess. We have seen such an abscess travel round the pelvis behind the rectum and form a swelling near the left broad ligament, which was thought by some to be a parametric abscess.

Seventh. The appendix may lie completely hidden in either the subcæcal or ileo-cæcal fossa, the mouth being closed. In cases such as these the vermiform appendix may require careful searching for, and, indeed, may be thought to be absent at first. Owing to the fact that the mouth of the fossa has been closed, it may be impossible to say whether the closed fossa was originally subcæcal or ileo-cæcal.

This condition was found twice, both times in male subjects.

Summary.

Appendix Vermiformis:—

Normal—

<i>Free, pervious,</i>	.	.	.	.	.	94	
<i>Free, obliterated,</i>	.	.	.	.	.	7	
<i>Free, with cysts,</i>	.	.	.	.	.	3	
						—	104

Abnormal—

1. Adherent to peritoneum in the sub-cæcal region,	.	.	.	.	.	7	
2. Adherent to the under surface of the cæcum,	.	.	.	.	.	9	
3. In the subcæcal fossa,	.	.	.	.	.	12	
4. Fixed to the right of the cæcum,	.	.	.	.	.	5	
						—	—
Carry forward,	.	.	.	.	.	33	104

Summary—continued.

<i>Abnormal—</i>	Brought forward,	33	10	3.
5. Adherent to the peritoneum in the region where the ileo-cæcal fossa developes,	. . . . .	12		fl
6. In the ileo-cæcal fossa,	. . . . .	9		
7. Hidden in fossa, the mouth of which had closed,	. . . . .	2		
		—	56	
			160	

The drawings which illustrate this communication have been made by Mr Lockwood from specimens which are in the St George's Hospital Museum.

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THE COMPARATIVE ANATOMY OF THE MUSCLES AND NERVES OF THE SUPERIOR AND INFERIOR EXTREMITIES OF THE ANTHROPOID APES.¹ By DAVID HEPBURN, M.D., F.R.S.E., *Senior Demonstrator of Anatomy, University of Edinburgh.* PART I. (PLATE III.)

SOME time ago, through the kindness of Sir William Turner, of the University of Edinburgh, and of Professor D. J. Cunningham, of Trinity College, Dublin, I found myself in the unique position of having the upper and lower limbs of each of the great Anthropoid Apes in my possession at the same time. From the former I received a young male Gorilla, and from the latter the upper and lower extremities of a Chimpanzee, an Orangutan, and a Gibbon. Accordingly, I determined to make fresh dissections of the limbs of these animals, and, while not ignoring what had previously been contributed to the literature of the subject, I wrote entirely independent descriptions of the various muscles and nerves as they presented themselves in my own dissections. They were described with the same attention to detail as the corresponding parts of human anatomy, and that quite irrespective of their frequent close resemblance to their representatives in Man. When the detailed descriptions were completed, I went carefully over them a second time, instituting a series of comparisons which were set forth in a separate chapter of the thesis, and which constitutes the bulk of the following pages.

As a result, it will be found that many of the seeming

¹ This paper consists mainly of extracts from my Thesis presented to the Medical Faculty of the University of Edinburgh, for which a Gold Medal and the degree of Doctor of Medicine were awarded, Aug. 1, 1891.

anomalies in the anatomy of the limbs of Man have found intelligent explanation, and the general facts of the comparative anatomy of the limbs of mammalia have been frequently corroborated.

With regard to the question of the nerve-supply of muscles affording a key to muscle homologies, I am of opinion that my dissections will show that there are exceptions to this rule; and, therefore, I cannot agree with Gegenbaur and Ruge in regarding nerve-supply as an infallible guide to muscle homology. As illustrating the possibility of variation, I would specially direct attention to that part of the comparative statement which deals with the flexor brevis pollicis muscle, and also to the remarkable variation in the nerve-supply of the pronator quadratus muscle of the Gibbon. There can be no doubt that it is the pronator quadratus muscle which is situated transversely between radius and ulna on the anterior aspect of the forearm immediately above the wrist-joint, and yet in this case it undoubtedly received its nerve-supply from the *posterior interosseous nerve*, which required to perforate the delicate interosseous membrane before it could enter the deep surface of the muscle in question. This instance alone would be sufficient to show that nerve-supply is not an absolute guide in determining muscle homologies.

Among other interesting points, these dissections throw light on the composition of the human coraco-brachialis muscle; on the development of the extensores ossis metacarpi pollicis et primi internodii pollicis; on the line of cleavage of the flexor profundus digitorum, in order to account for its double nerve-supply in Man; on the composite nature of the adductor magnus muscle, as indicated by its double nerve-supply; on the presence of the obturator nerve in relation to the posterior aspect of the knee-joint; on the double nerve-supply of the pectineus muscle as described in Man; on the probability of the peroneus brevis being the outer segment of a fibular extensor, the remainder of which, as suggested by Ruge, has moved downwards to the dorsum of the foot, where it remains as the extensor brevis digitorum; on the development of the long flexor tendons in the sole of the foot; on the arrangement of the dorsal interosseous muscles of the foot in relation to a

median line which tends to move from the medius to the index digit, in virtue of a changing mode of pedal progression.

This enumeration merely includes the principal features of the results obtained, and it will be seen that the dissection of these Anthropoid Apes has enabled me to formulate a remarkable series of deductions.

In the following pages each muscle will be referred to under its own name, but the details of its description will either be omitted or subordinated to its comparative aspects. Here I may be permitted to state that, in the case of the Gorilla, my manuscript was completed before the monograph of Eisler on "Das Gefäss- und Periphere-Nervensystem des Gorilla" came into my hands.

MYOLOGY OF THE SUPERIOR EXTREMITY.

Muscles of the Shoulder Girdle.

Trapezius.—In all the four Apes this muscle formed a continuous sheet, and although the origin was incomplete in two of them (Chimpanzee and Gibbon), still there was evidence that the general origin in all of them was fairly similar.¹ In the Gorilla the occipital origin was slightly more extensive than in Man, while in the Orang it was considerably more extensive, and ran outwards to the mastoid process of the temporal bone, where it came in contact with the posterior border of the sternomastoid muscle, and formed an accurate apex for the posterior triangle of the neck.

As regards the insertion, in all of them it was practically alike and similar to the arrangement found in Man, but in the Orang fibres were inserted into the upper surface as well as into the posterior border of the acromial end of the clavicle.

Latissimus Dorsi.—In general appearance this muscle corresponded to that found in Man, but there were variations in the character and extent of its origin. In the Gorilla and Orang it arose from the spinous processes and supra-spinous

¹ The animals lent by Professor Cunningham had been divided mesially, and in consequence the origins of muscles arising from the mesial line were fragmentary or absent.

ligaments of the three lower dorsal vertebrae. (In the Chimpanzee and Gibbon this part of the origin was mutilated.) The origin from the iliac crest varied in its amount: in the Chimpanzee it arose by fleshy fibres from the anterior half of the outer lip of the crest, while in the Orang it reached to within half an inch of the anterior superior spine. There were no digitations from ribs in the case of the Orang, but in the three other apes these were present—the Chimpanzee having three, the Gibbon five, and the Gorilla six.

In no case was there any additional origin from the inferior angle of the scapula over which the muscle ran to its insertion, narrowing down into a flattened tendon as it proceeded outwards. In each case the insertion was into the bottom of the bicipital groove of the humerus in front of the insertion of *teres major*. In the Chimpanzee and Orang a few muscular fibres from the *latissimus dorsi* were inserted into the posterior aspect of the tendon of the *teres major*, while in the Gibbon these two tendons were inseparably blended at their insertions.

Rhomboideus (Major et Minor).—In the Gibbon this muscle was entirely destroyed owing to the line of section, and for the same reason it was incomplete in the Orang and Chimpanzee, but wherever it could be examined it showed a muscle indivisible into component parts. There was no occipital origin in the Gorilla; but, on the other hand, its origin from the spinous processes of the dorsal vertebrae extended as low down as the 6th dorsal vertebra. The occipital origin was found in the Orang.

As regards the insertion of this undivided muscle, it was attached to the vertebral border of the scapula: in the Orang and Chimpanzee, from the inferior angle upwards to a point about an inch above the base of the scapular spine; in the Gorilla, from the inferior angle to a point opposite the base of the scapular spine.

Levator Anguli Scapulæ.—(This muscle could not be examined in the Gibbon.) In the Orang, Chimpanzee, and Gorilla this muscle was present in a well-developed state, but in the Orang the individual fasciculi, of which the muscle is composed, remained separate from each other until near their common insertion, when they amalgamated to form the usual mass. In the three animals named, the insertion occupied the remainder

of the vertebral border of the scapula not already taken up by the rhomboideus. In the Chimpanzee there were *three* slips of origin from the transverse processes of a corresponding number of the upper cervical vertebræ; in the Gorilla, *four* slips of origin of a similar kind; and in the Orang, *five* slips of origin—four of them from the transverse processes of the upper four cervical vertebræ, and the remaining one from the outer surface of the mastoid process under cover of the sternomastoid muscle. This mastoid origin in the Orang was quite distinct, and separated by a considerable interval from the occipital origin of the rhomboideus in the same animal, but their muscular fibres blended intimately close to the scapula.

Pectoralis Major.—The arrangement of the pectoral muscles closely resembled the condition which prevails in Man. They were arranged in two strata—the pectoralis major and pectoralis minor. In all the four animals the pectoralis major consisted of two distinct portions—an upper or clavicular and a lower or sternal—both of which were well marked in the Gorilla, and separated from each other by an intermuscular interval half an inch in width at its sternal end; but, in the Chimpanzee, there was no cellular or intermuscular interval between these two origins. On the other hand, in the Orang the upper portion of the muscle, although separated from the remainder of the muscle by a very distinct cellular interval, received no fibres whatever from the clavicle, but arose from the manubrium sterni and the cartilage of the 1st rib. In the Gibbon, again, the cellular interval between the clavicular and sternal origins did not extend through the entire thickness of the muscle. In none of the apes was there any distinction of the lower fibres, viz., those arising from the aponeurosis of the external oblique muscle of the abdomen—into a pectoralis quartus. In each animal there was a marked crossing of the fibres from the two main sources of origin as they approached their line of insertion, which was into the outer lip of the bicipital groove of the humerus, or external to the long tendon of the biceps when the groove was deficient or shallow, as it was in the Gorilla, in which the insertion extended from the surgical neck of the humerus almost as low down as the insertion of the deltoid muscle.

Pectoralis Minor.—In every instance this muscle was quite

distinct from the pectoralis major. While it had the same general direction and attachments as the corresponding muscle in Man, yet it showed considerable variety both in regard to its origin and insertion in the different Apes. Thus, for example, the origin in the Gorilla was by a series of slips arising from the 3rd to the 7th ribs, both inclusive, close to the junction of rib with costal cartilage; in the Chimpanzee, from the 2nd, 3rd, and 4th ribs in a similar position; in the Orang, from the 3rd and 4th ribs opposite the junction of rib with costal cartilage; in the Gibbon, from the 3rd, 4th, and 5th ribs. In all the four animals the tendon of insertion passed obliquely upwards and outwards superficial to the axillary artery, but there was a different method of insertion in each case. Thus, in the Gorilla, the rounded tendon was inserted into the inner border of the coracoid process near to its tip; in the Orang, the rounded tendon was inserted into the upper surface of the coracoid process near its base. In the Gibbon, there were three points of insertion—(a) into the under surface of the shaft of the clavicle, just external to its middle; (b) into the inner border of the coracoid process; (c) into the common tendon of origin of the coraco-brachialis and biceps (short head), a short distance below the tip of the coracoid process.

In the interval between insertion (a) and insertion (b) one of the nerves for the pectoralis major passed through, and since it is customary to find this nerve *perforating* the pectoralis minor of Man, we are fairly entitled to consider this clavicular insertion as a part of pectoralis minor, and not a displaced portion of the subclavius. Besides, as we shall afterwards see, the subclavius muscle of the Gibbon had an origin from the 3rd rib subjacent to, and perfectly distinct from, the clavicular insertion of pectoralis minor just referred to.

In the Chimpanzee, the rounded tendon of insertion passed above the coracoid process, and was continued outwards beneath the coraco-acromial ligament to be inserted into the capsule of the shoulder-joint, partly directly, and partly with the tendon of the supraspinatus.

The manner of insertion of the pectoralis minor in the Chimpanzee corresponded to what is found in some of the lower mammalia, and even as low down as the marsupials, as has been

pointed out by Professor Cunningham¹ in the *Challenger Reports*.

Subclavius.—In the Gorilla and Chimpanzee, this muscle did not present any noteworthy difference from the condition in which it is found in Man. On the other hand, it had an additional slip of origin from the 2nd rib in the case of the Orang, and in the case of the Gibbon it had no origin from the 1st rib, but derived slips from the 2nd and 3rd ribs—the latter slip being quite distinct from one which arose from the same rib and belonged to pectoralis minor. With the exception of the Gibbon, the insertion of this muscle agreed with its insertion in Man. In the Gibbon the insertion included the inferior and posterior surfaces of the outer half of the shaft of the clavicle.

Deltoid.—In all the animals examined this muscle had practically the same disposition as the corresponding muscle in Man, and in one animal it was essentially the same as in another. In the Gibbon the area of its insertion into the shaft of the humerus was more elongated than in the others, but in no instance did it extend beyond the middle of the outer surface of the humeral shaft. As in Man so in the Apes; the three origins from clavicle, acromion, and spine of scapula were fused together to produce a single muscle. It is worthy of note that in the Chimpanzee the clavicular part of the muscle was intimately connected with the clavicular part of the pectoralis major near their insertions.

Supraspinatus.—In all the dissections this muscle was smaller than the infraspinatus, and each one closely resembled its prototype in Man. The only exception was found in the Chimpanzee, in which a considerable part of the tendon of the pectoralis minor joined the tendon of this muscle.

Infraspinatus.—This muscle also closely resembled the corresponding muscle in Man, and there were no striking differences to be observed in comparing one muscle with the other. In the Chimpanzee the great obliquity of the scapular spine reduced the proportion in size between infraspinatus and supraspinatus.

¹ *Challenger Reports*, part xvi., "Report on Marsupials," p. 8.

Teres Minor.—This was a distinct muscle in all the dissections, and, with the exception of the Gibbon, it was more or less visible while the deltoid was yet in position. In the Gibbon no part of the muscle was visible until the deltoid was reflected. In all it arose from the axillary border of the scapula on its dorsal aspect. In the Gibbon it occupied an inch of the border close to the glenoid cavity; in the Orang, one-half of the border; in the Chimpanzee, the upper two-thirds; and in the Gorilla, the middle third.

From these observations it will be seen that the Chimpanzee most nearly presented the condition of the muscle as found in Man, and herein my dissection differs from that of Champneys,¹ who found the muscle attached to the middle third of the ventral border of the scapula. In each case the insertion was as in Man.

Teres Major.—In each animal this muscle arose from the dorsal surface of the inferior angle of the scapula, and from a varying amount of the axillary border, being greatest in the Gibbon, and to the smallest extent in the cases of the Gorilla and Orang, where it only occupied the lower third of the border. In all it was inserted into the inner lip of the bicipital groove of the humerus, more or less intimately blended with the insertion of the latissimus dorsi. In the Gorilla it extended lower down than the latissimus dorsi, and in the Gibbon the latissimus dorsi folded itself round the lower margin of the tendon of the teres major.

Subscapularis.—In all, this muscle was well marked, and in its arrangement and attachments it presented no points of noteworthy difference from the condition which prevails in Man.

Serratus Magnus.—In every instance this muscle formed a continuous sheet, arising from a varying number of ribs. In the Orang it arose from the upper ten ribs; in the Chimpanzee and Gibbon, from the upper eleven ribs; in the Gorilla, from all—thirteen ribs. In none of them was there any cervical part, although Champneys² found such a portion in his Chimpanzee. The insertions occupied the usual amount of the vertebral border of the scapula on its ventral aspect, as seen in Man.

¹ *Jour. Anat. and Phys.*, vol. vi., 1872.

² *Loc. cit.*

(In the Gibbon the insertion had been removed in the plane of section.)

Muscles of the Upper Arm.

Coraco-Brachialis.—No statement regarding the comparative anatomy of this muscle would be complete without reference to the paper on “Muscular Variations” by Professor John Wood,¹ in which he teaches the threefold constitution of this muscle—coraco-brachialis brevis, coraco-brachialis medius, and coraco-brachialis longus. In the Gibbon this was a single muscle; moreover, it was not pierced by the musculo-cutaneous nerve which travelled along its inner surface and crossed outwards and downwards at its lower border. In the Chimpanzee and Orang the muscle was distinctly double, and the musculo-cutaneous nerve passed outwards and downwards between the two parts. In the Gorilla the condition of this muscle presented variations on the two sides of the body. On the right side the coraco-brachialis arose from the tip of the coracoid process of the scapula by a tendon common to, inseparably blended with, and under cover of the origin of the short head of the biceps. From this origin the muscle passed downwards and backwards to be inserted into the middle third of the inner surface of the shaft of the humerus. From the lower border of the muscle a few fibrous strands passed downwards superficial to the musculo-cutaneous nerve and became attached to the internal inter-muscular septum, and probably these represent coraco-brachialis longus. In addition to the parts above described, the left side showed that a few muscular fibres—sufficient to make a bundle considerably less than a lumbrical muscle—left the under surface of coraco-brachialis to be inserted into the inner side of the neck of the humerus above the level of the teres major tendon, and doubtless these fibres represent the coraco-brachialis brevis. In this animal we have, therefore, representatives of the three primary components of the coraco-brachialis muscle, and of these, two are extremely rudimentary, while the coraco-brachialis medius persists. These observations agree with the experience of Champneys² and Vrolik³ in the Chimpanzee, with Church⁴ in

¹ *Jour. Anat. and Phys.*, vol. i.

² *Loc. cit.*

³ *Recherches d'Anat. sur le Chimpanzé*, 1841.

⁴ Church, *Nat. Hist. Review*, Jan. 1862.

the Orang, with Kohlbrügge¹ in the Gibbon; but they differ from Duvernoy² in the Gorilla.

According to Wood, the coraco-brachialis brevis is inserted into the humerus above the tendon of the teres major, the coraco-brachialis medius into the humerus about its middle, and the coraco-brachialis longus into the lower part of the shaft of the humerus on its inner aspect in the region of the supra-condyloid ridge.

In none of my specimens, except in the left arm of the Gorilla, could the coraco-brachialis brevis be said to exist, for in all the others the highest part of the muscle did not come superior to the insertion of the teres major, whereas in the Gibbon, where the muscle was single, it extended well down below the lower border of teres major. On the other hand, in the Chimpanzee and Orang, where the muscle was double, the lower portion ran down to the upper part of the internal supra-condyloid ridge.

The conclusion is, therefore, forced upon us that the coraco-brachialis medius is the representative of this group of three muscles in the Gibbon and Gorilla, while in the Chimpanzee and Orang the coraco-brachialis medius and coraco-brachialis longus are both present. As the coraco-brachialis longus becomes shorter, it rises higher on the shaft of the humerus, until it fuses with the medius, and the condition found in Man is the result, in whom an apparently single muscle is perforated by the musculo-cutaneous nerve.

Biceps Flexor Cubiti.—In the Gorilla, Chimpanzee, and Orang, this muscle possessed the usual well-known features which characterise the corresponding muscle in Man; but in the Gibbon the short head of the muscle has become detached from the coracoid process, and was found arising from the margins of the upper part of the bicipital groove of the humerus covering the rounded tendon of the long head, which arose from the apex of the glenoid fossa of the scapula inside the capsule of the shoulder-joint. In the same animal the muscles round the elbow-joint were considerably fused together, and the

¹ Kohlbrügge, *Anatomie des Genus Hylobates*, 1890 (Dr Max Weber, Amsterdam).

² Duvernoy, *Archives du Museum d'Hist. Nat.*, viii.

biceps received fibres of origin from the whole length of the anterior surface of the internal intermuscular septum, thereby forming a complete muscular covering for the brachial nerves and vessels which were not visible from the inner aspect of the upper arm.

Brachialis Anticus.—In all essential details this muscle corresponded to the same muscle in Man, and even in the Gibbon the points of difference were very small. In it we may note the fact that the highest limit of the muscle did not reach the coraco-brachialis, and neither did it embrace the insertion of the deltoid where it was found anterior to, but not behind, the insertion of the deltoid muscle.

Triceps Extensor Cubiti.—In all the animals under consideration this muscle was strongly developed, and presented the characteristic arrangement from which it derives its name. The long or scapular head had a more extended origin than is usually found in Man. In each case there was a series of more or less fleshy fibres arising from the upper third or half of the axillary border of the scapula, and situated between the origins of teres minor and teres major. These fibres were in direct continuity with the long head, and were not separable into a distinct origin apart from the long head. The outer and inner heads of the muscle and the insertion of the whole had the usual arrangement found in Man.

Anconeus.—In all the specimens this small muscle was distinctly developed, and had its customary attachments, but in the Orang and Gibbon the upper margin of the muscle was ill defined, being in reality a continuation of the triceps, while in the latter ape its fibres blended with those of the extensor carpi ulnaris.

Latissimo-Condylodeus (Dorsi-epitrochlear).—This muscle was found in each animal. It arose from the tendon of latissimus dorsi, about 1 inch from its insertion, but in no case did it reach the internal condyle, and its insertion was into the internal intermuscular septum between the coraco-brachialis and internal condyle. It always had a distinct branch from the musculo-spiral nerve, and it is therefore to be regarded as a separate muscle, since the latissimus dorsi is supplied by the long subscapular nerve.

Muscles of the Forearm.

Pronator Radii Teres.—In all, this muscle was well developed, but in the Gorilla and Gibbon no coronoid head was found. In the Chimpanzee and Orang the coronoid head was well represented, and the median nerve passed between the humeral and coronoid origins. In the two latter animals the insertion was somewhat lower down than in Man, the lowest part of the insertion being fleshy. In the Gibbon the insertion was into the anterior surface as well as the outer border of the radius.

Flexor Carpi Radialis.—This was also a well-marked muscle throughout the series, its general origin, course, and insertion being similar in each animal, and agreeing with the conditions found in Man. In the Gorilla, Orang, and Gibbon there was an additional source of origin from a fibrous septum attached to the oblique line of the radius immediately internal to the insertion of pronator radii teres. In the Gorilla this additional origin extended some distance lower down than the insertion of the pronator teres. This origin was not present in the Chimpanzee. All of them agreed in their double insertion into the palmar aspects of the bases of the second and third metacarpal bones.

Palmaris Longus.—This muscle was present in all except the Gorilla, and it had its usual origin, course, and insertion after the manner of its disposition in Man.

Flexor Sublimis Digitorum.—The points wherein differences could be noted in this muscle throughout the series of animals, and in the corresponding muscle of Man, were very few. In all, the origin presented condylar, coronoid, and radial parts; but, in addition to these, in the Gibbon it showed an additional origin from rather more than the middle two-fourths of the anterior surface of the shaft of the ulna, between flexor carpi ulnaris and flexor profundus digitorum. In each animal the muscle provided four tendons for the four inner digits. In the Gibbon, it may be noted that the 2nd and 3rd digits received their tendons from the radial segment or aspect of the muscle, while the ulnar side of the muscle supplied tendons to the 4th and 5th digits. This is not the case in the Orang and Chim-

panzee, in which the tendons for the 3rd and 4th digits arose from that part of the muscle situated radiad, while the tendons for the 2nd and 5th digits spring from that part of the muscle placed ulnad, and hence it follows that the tendon for the 2nd or index digit crossed obliquely outwards beneath those for the 3rd and 4th digits. The same remarks apply to the arrangement of the tendons in the case of the Gorilla. In the palm of the hand the tendons were bound more firmly in position by means of deep and powerful prolongations of the palmar fascia than is the case in Man, so that each tendon was practically enclosed in a sheath from the point of its emergence from under the anterior annular ligament, but after entering the flexor sheaths on the palmar aspects of the fingers, their disposition and insertions were similar to those of Man.

Flexor Carpi Ulnaris.—In each of the animals this muscle had a similar disposition, and throughout it closely resembled the corresponding muscle in Man. In each it had a condylar and an olecranon head of origin, as well as an attachment to the shaft of the ulna by means of an aponeurosis. In the Orang the origin from the olecranon was aponeurotic and not muscular. In all, the ulnar nerve entered the forearm between the condylar and olecranon heads. In every instance the tendon of the muscle was inserted into the pisiform bone.

Flexor Longus Pollicis; Flexor Profundus Digitorum.—We now come to the consideration of a stratum of muscle placed beneath the superficial group of flexors. In many of the lower animals this mass is intimately associated with the flexor sublimis digitorum, and in the Gibbon we still find a remnant of this arrangement, for in it the stratum under discussion possessed a source of origin from the internal condyle of the humerus. We therefore see that this deep stratum represents the radial and ulnar segments of the muscular mass, which in the lower animals is divisible into condylar, radial, and ulnar segments. In the Gorilla, Orang, Chimpanzee, and Man the condylar segment has become completely differentiated as flexor sublimis digitorum; but in the Gibbon a portion of this segment is still found extending from the internal condyle to the deep stratum. In Man this condition is occasionally found as a muscular variation. The radial and ulnar segments are responsible for the production of

five tendons—one for each digit. Of these, the tendon for the pollex becomes the flexor longus pollicis, while those for the remaining digits constitute the tendons of the flexor profundus digitorum. In the Gibbon this stratum of muscle did not present the same distinct line of segmentation into radial and ulnar portions which it did in the other three apes; but those parts arising from the radius and humeral condyle, *i.e.*, the humero-radial segment, gave origin to three muscular bellies, ending in rounded tendons, distributed to the thumb, index, and middle fingers, and supplied by the median nerve. The ulnar segment of the stratum gave origin to two muscular bellies, sending tendons to the ring and little fingers, and supplied by the ulnar nerve.

In the Orang, Chimpanzee, and Gorilla the natural line of segmentation was such that, of the *five* tendons, my series of dissections showed that *three*, viz., those for the 3rd, 4th, and 5th digits, were provided by the ulnar segment; while *two*, viz., those for the pollex and index, were provided by the radial segment; but still the median nerve supplied three of the muscular bellies and the ulnar nerve supplied two. Concentrating our attention on the radial segment, the Gibbon shows that it produces a distinct rounded tendon (associated with a small fleshy belly) for the thumb,—this constitutes a true flexor longus pollicis,—and, in addition, separate tendons for the index and middle fingers—their deep flexors. In the Chimpanzee the radial segment provided one powerful tendon, the bulk of which went to the index finger, and only a small offshoot reached the thumb, where it occupied the position of the long flexor tendon. In the Orang the same arrangement was found as in the case of the Chimpanzee, only the offshoot for the thumb had almost lost its attachment to the tendon for the index finger, and therefore its action as a deep flexor for the thumb must be of the feeblest kind. In the Gorilla, on the other hand, the radial segment only provided one tendon, viz., that for the index finger; but an examination of the flexor aspect of the thumb revealed a tendinous band, occupying the position of the long flexor, and attached by one end to the carpus, and by the other to the palmar aspect of the base of the terminal phalanx of the thumb (fig. 6). Clearly this fibrous band was of no value

as a flexor, and therefore we may consider that the Gorilla has lost its flexor longus pollicis. It is certainly somewhat remarkable that the tendon of the flexor longus pollicis should present a different disposition in each of the Apes, although the muscular mass from which it might be expected to arise is well developed.

We can now understand how this radial segment differentiates more and more, so as to provide deep flexors for the thumb and index finger as the specialisation of function advances. Gradually that portion associated with the thumb increases, and dissociates itself from the part belonging to the index finger until the pollical portion grows large enough to assume the position and importance of the flexor longus pollicis as we see it in Man. By this time that part belonging to the index finger has been moved towards the ulnar segment, with which it ultimately fuses, and forms part of the flexor profundus digitorum as it is found in Man. The tendency seems to be for the line of vertical cleavage into radial and ulnar segments to move towards the radial side; for, whereas, in the Gibbon three tendons lie to the radial side of this line of cleavage, in the Orang, Chimpanzee, and Gorilla only two tendons lie to the radial side, and, finally, in Man the number is reduced to one, viz., flexor longus pollicis, by reason of the line of cleavage having again moved still more towards the radial side.

Further, we are in a position to explain the double nerve-supply of the flexor profundus digitorum of Man by an examination of the nerve-supply of the radial and ulnar segments previously referred to. The radial segment is supplied directly from the median nerve, while the radial aspect of the ulnar segment derives its nerve-supply from the anterior interosseous branch of the same nerve, i.e., in each Ape the same amount of the stratum is supplied by the median nerve. Hence, it follows that muscular substance to correspond with three of the five deep tendons derives its nerve-supply from the median nerve, and the remaining muscular substance for the two innermost tendons is supplied from the ulnar nerve—that is to say, the flexor profundus digitorum, as we understand it in Man, has its ulnar half supplied by the ulnar nerve, and its radial half supplied by the median nerve; and as we know the same plan of nerve-supply persists all through this muscle,

affecting even the lumbricales associated with these deep tendons in the palm, and thereby the two outer lumbrical muscles are provided with branches from the median nerve, and the two inner lumbricales with branches from the ulnar nerve.

Lumbricales.—In each of the Apes examined these muscles were present, and *four* in number. They had a tendency to decrease in size from the first to the fourth. As regards their origins they were subject to variety. The first always arose from a single tendon; in the Chimpanzee and Gibbon the second also arose merely from the radial side of the deep tendon for the middle digit; in all, the third had a double head of origin. In the Chimpanzee the fourth arose only from the ulnar side of the deep tendon for the ring finger, and in the Orang the fourth arose from the radial side of the deep tendon to the 5th digit. Their insertions were similar to those found in Man.

Pronator Quadratus.—In all the series this muscle was present, but was most feeble in the Orang, in which there was scarcely enough of muscular fibre to make a continuous layer. It had its usual position at the lower end of the forearm, but the direction of its fibres was, as a rule, more oblique than in Man. This was especially the case in the Gibbon and Orang, in which it distinctly lay from above downwards and outwards.

Turning now to the muscles on the extensor aspect of the forearm, we find that just as in Man, so in all the animals under consideration they arrange themselves in a superficial and a deep group.

Supinator Radii Longus.—In all the series of dissections this was a distinct muscle, and in each instance it took origin from more or less of the external supracondyloid ridge and septum higher up than the other muscles arising from the same ridge. In the Chimpanzee it extended as high as the insertion of the deltoid, and in the Gibbon it was intimately blended with the outer surface of the brachialis anticus. In every case its course lay along the radial border of the forearm to its point of insertion, which varied in the different animals. In the Gorilla the insertion was the same as in Man; in the Chimpanzee the tendon was attached to the radius for $\frac{1}{2}$ inch above the styloid process; in the Orang this attachment had increased to 1 inch in length; while in the Gibbon, not only was it attached

to the anterior surface and outer border of the radius for $2\frac{1}{2}$ inches, but it failed to reach the styloid process by a distance of $2\frac{1}{2}$ inches.

Extensor Carpi Radialis Longior.—In its general arrangement this muscle was similar to its fellows throughout the series as well as to the corresponding muscle in Man. It arose from the lower part of the external supracondyloid ridge and septum: in the lower part of the forearm it was crossed superficially by special extensors of the thumb, and it was inserted into the radial aspect of the base of the metacarpal bone of the index finger on its dorsal surface. In the Gibbon its muscular belly was little more than 3 inches in length, while its tendon measured 10 inches, and in addition to the usual insertion it sent a prolongation to the base of the 1st metacarpal bone on its ulnar side.

Extensor Carpi Radialis Brevior.—Although in intimate relationship to the preceding muscle, it was in no way amalgamated therewith, and it possessed the same general features throughout the series, and closely resembled the corresponding muscle in Man. In the Orang and Chimpanzee it derived fibres of origin from the external lateral ligament of the elbow-joint. In all four animals its insertion resembled that found in Man.

Extensor Communis Digitorum.—In all its features this muscle throughout the series harmonised closely with the corresponding muscle in Man. In the Gibbon the tendon to the annularis sent a small slip to the minimus. The arrangement of the tendons on the dorsum of each digit was the same as is commonly found in Man.

Extensor Minimi Digiti.—This muscle had the familiar origin seen in Man in the case of the Orang and Chimpanzee, but in the Gorilla and Gibbon its origin was from a septum placed between the extensor communis digitorum and the extensor carpi ulnaris rather than from the external condyle of the humerus. Its course and insertion were similar to those in Man in all except the Orang, in which it divided into two tendons on the dorsum of the carpus. These were distributed to the 4th and 5th digits, where they joined the tendons from the common extensor. This arrangement affords evidence of

its being the same muscle as the extensor digitorum secundus of the marsupials to which Professor Cunningham has directed attention in his memoir.¹

Extensor Carpi Ulnaris.—In each of the animals examined the arrangement of this muscle corresponded with that which prevails in Man, and in all, the insertion was a single one into the ulnar side of the base of the 5th metacarpal bone.

Extensor Indicis vel Extensor Profundus Digitorum.—With the exception of the Gorilla, in which this was a slender muscle, in the other animals it showed a considerably greater development than in Man. As far as the origin was concerned, it closely resembled the condition present in Man, but in regard to the insertion there were great differences. In the Gorilla, it resembled that of Man; in the Chimpanzee, it supplied tendons to the index and annularis; in the Orang, it supplied tendons to the index and medius; in the Gibbon, it supplied tendons to the index, medius, and annularis. In addition, these tendons in the case of the Orang sent slips, which were inserted into the dorsal surface of the bases of the 1st phalanges, and in the Gibbon they were entirely inserted into the dorsal surfaces of the bases of the 1st phalanges, and did not become blended with the common extensor expansion.

Supinator Brevis.—In all the animals this muscle was well marked, and practically it was identical throughout the series. Moreover, it corresponded closely with the same muscle in Man in regard to all essential details.

There are three special muscles for the pollex taking origin from this, the extensor aspect of the forearm. Undoubtedly these represent the three special extensors of the thumb of Man, but, on account of their insertions being considerably modified in two instances, it is necessary to make a change in the nomenclature to suit these special requirements. The following tabular statement gives the terms which are synonymous:—

- I. Extensor Ossis Metacarpi Pollicis *vel* Abductor Pollicis Longus.
- II. Extensor Primi Internodii Pollicis *vel* Extensor Pollicis Brevis.

¹ *Challenger Reports*, part_xvi., "Report on Marsupials," p. 15.

III. Extensor Secundi Internodii Pollicis *vel* Extensor Pollicis Longus.

In the course of our examination we shall find that III. is a constant muscle throughout the series, but that I. and II. are more or less amalgamated at their origins; that the two tendons arising therefrom always occupy the positions characteristic of them; but that in three of the animals—viz., Chimpanzee, Orang, and Gibbon—the tendons have failed to reach the insertions peculiar to these extensors as found in Man, and that the modified or synonymous terms are thereby rendered necessary.

Commencing with the *Extensor Ossis Metacarpi Pollicis vel Abductor Pollicis Longus*, we find that, in the Gorilla, this muscle occupied its ordinary position, and had its usual insertion into the base of the 1st metacarpal bone (fig. 2). The origin of this muscle was, however, inseparably amalgamated with that of the extensor primi internodii pollicis.

In the Chimpanzee, Orang, and Gibbon this muscle was always the highest of the three special muscles under consideration, and its special insertion in these animals necessitates the alternative terms. In all of them it was inserted in relation to the outer side of the carpus, viz., in the Gibbon, into a sesamoid bone (prepollex) (fig. 1); in the Chimpanzee, into a sesamoid bone and the trapezium; in the Orang, into a sesamoid bone and the base of metacarpal I. From these data it must be quite evident that it is one and the same muscle which runs through this series of variations.

Extensor Primi Internodii Pollicis vel Extensor Pollicis Brevis.—Dealing now with this muscle, there was no difficulty in recognising from its line of origin,—which was always more especially the posterior surface of the radius lower down than the preceding muscle, with which it was closely amalgamated in the Gorilla and Chimpanzee,—that it was the extensor primi internodii pollicis. But when we come to examine its insertion, then this name will not always apply. In the Gibbon, Orang and Chimpanzee, it was inserted into the base of metacarpal I. (fig. 1). In the Gorilla it was inserted into the base of *metacarpal I. and the base of the 1st phalanx of the thumb* (fig. 2). Considered in this way, as well as from its general relationships,

it seems to me that the above synonymous terms are fully warranted. Certainly, in three of the animals examined, this muscle had no insertion into the 1st phalanx of the pollex, but I do not think it is necessary to say that extensor primi internodii pollicis *vel* extensor pollicis brevis is on that account absent.¹ It is better to look upon the muscle as imperfectly developed, for, in the Gorilla, we see how very easily it might move forward to its true position.

Extensor Secundi Internodii Pollicis vel Extensor Pollicis Longus.—There was no difficulty whatever in determining this muscle. Its position, origin, course, and point of insertion, all indicated that it was the homologue of the corresponding muscle in man. There were, however, some points of great interest in connection with its insertion. We have seen that in the Gibbon, Orang, and Chimpanzee, the true extensor of the first phalanx of the pollex failed to reach this bone. Now, *in each of these cases*, a prolongation from the tendon of extensor secundi internodii pollicis supplied the deficiency, and it was inserted into the base of phalanx I. In the Gorilla, on the other hand, where the true extensor of the 1st phalanx was present, there was no additional slip from the extensor of the 2nd phalanx. Another extremely interesting feature of the tendon was found in the Gorilla, in which this muscle sent a tendon to the index as well as the special one to the pollex. The importance of this additional slip is seen when we remember that in lower forms, *e.g.*, marsupials, we may find as many as three tendons from this muscle.²

The Posterior Annular Ligament.—Throughout the series of dissections this strong ligament had the same number of synovial compartments and transmitted the same groups of tendons as in Man, and it presented no features requiring special mention.

Intrinsic Muscles of the Hand.—This term includes those muscles which are left after the flexors, extensors, and lumbricales are removed. They consist of groups of muscles which fulfil the functions of adductors, abductors, and short flexors of the various digits.

¹ Champneys, *loc. cit.*

² Cunningham, *loc. cit.*

Abductor Pollicis (Brevis).—In its general arrangement this muscle was similar throughout the series. In the Gorilla and Orang the muscle had no direct attachment to the carpal bones, its origin being from the radial aspect of the upper part of the palmar surface of the anterior annular ligament, but in the Gibbon and Chimpanzee it received in addition fibres of origin from the scaphoid and the sesamoid bone (prepollex). As regards its insertion, in all it was attached to the radial side of the base of the 1st phalanx of the pollex. In addition, in the Chimpanzee it gave a prolongation to the base of the terminal phalanx, and in the Gibbon it was attached to the head of the 1st metacarpal bone.

Opponens Pollicis.—In the Gibbon this muscle differed somewhat from the others by reason of its projecting towards the palm between the heads of the flexor brevis pollicis. In the other animals its position was the usual one, under cover of the abductor pollicis to a greater or less extent. The insertion closely corresponded with the condition found in Man, except in the Gibbon, where, in addition to the metacarpal insertion, slips were sent forward to the radial side of the bases of the 1st and 2nd phalanges.

Adductor Pollicis Transversus.—In every instance this muscle was intimately associated with a fibrous aponeurosis and septum, which ran distally from the base of the middle metacarpal bone. In all of the dissections there was a decided tendency for the muscle to become fasciculated, and in consequence each muscle in the series presented proximal and distal segments easily separable from each other. In the Gorilla the distal portion of the muscle had fibres of origin from the palmar surface of the distal third of the shaft of the 2nd metacarpal bone, while the proximal portion arose from the palmar aspect of the proximal half of the 3rd metacarpal bone. From such a wide origin there was naturally considerable convergence of the fibres as they passed outwards to their insertion. In the Gorilla, Chimpanzee, and Orang, the insertion was into the ulnar side of the base of the 1st phalanx of the pollex. So it was in the Gibbon, but in this animal there was no definite line of demarcation between this muscle and adductor pollicis obliquus, and so in addition it was inserted into the distal two-

thirds of the ulnar border of the 1st metacarpal bone. Reference will again be made to this additional insertion when discussing the homologies of the muscles of the foot.

Adductor Pollicis Obliquus.—Until recently, in descriptive human anatomy, this muscle was regarded as the inner or ulnar head of the flexor brevis pollicis, but the condition in which it is presented in the hands of the Apes greatly facilitates a proper conception of its nature. In the Gibbon, as we have already seen, there was no definite line of demarcation between the oblique and transverse segments of the adductor muscle, nevertheless the oblique portion arose from the palmar aspect of the base of the 2nd metacarpal bone and from the tendon of insertion of the flexor carpi radialis muscle, in close proximity to the carpus. The muscle is here presented in its simplest condition. In the Gorilla, Chimpanzee, and Orang, the adductor pollicis obliquus was distinctly separated from adductor pollicis transversus, but whereas in the Orang it did not extend any nearer to the carpus than the corresponding part of the adductor muscle of the Gibbon, in the Gorilla it arose from the front of the carpus in the region of the os magnum, and in the Chimpanzee from the aponeurosis covering the base of the 3rd metacarpal bone, from the radial side of the os magnum, and from the sheath of the tendon of the flexor carpi radialis. In all this we see its close similarity to the corresponding muscle in Man, and moreover we may trace its tendency to move proximalwards and radiad, so that ultimately it assumes a position which led to its being mistaken for the inner head of the flexor brevis pollicis, an error which occurred all the more readily as, in presence of this actively developing muscle, the true inner head of the short flexor of the thumb was liable to be diminished in size or crowded out of existence.

The insertion of this muscle was fairly constant in all the Apes, being in association with the oblique adductor.

The writings of Cunningham,¹ Bischoff,² and Halford³ have taught us to regard the adductor pollicis (oblique and transverse)

¹ Cunningham, *Jour. Anat. and Phys.*, 1878.

² *Beiträge zur Anatomie des Hylobates leuciscus*, München, 1870 ; *Beiträge zur Anatomie des Gorilla*, München, 1879.

³ *Lines of Demarcation between Man, Gorilla, and Macaque*, Melbourne, 1864.

as one of a special group of adductors, to which Professor Halford applied the name of "contrahentes digitorum," a name which has been generally adopted. Considering the muscle just described as one member of this series, there remain others, which are also adductors, towards the median line of the hand. In the Gorilla and Orang no other contrahentes were seen (figs. 4 and 6), although in the latter animal the palmar interossei—which are also adductors—received fibres of origin from the deep aspect of the aponeurosis, with which the adductor pollicis was associated. In the Chimpanzee, on the other hand, there were two small muscles belonging to this group (fig. 5). These arose from the ulnar aspect of the median septum and aponeurosis, and were inserted so as to act as adductors of the annularis and minimus. In the Gibbon, the number of contrahentes was four, and they acted as adductors of the pollex, index, annularis, and minimus respectively (fig. 3).

Flexor Brevis Pollicis.—A mere glance is sufficient to satisfy us that in each of the Apes, as in Man, this muscle in its primitive form possessed two heads—an outer or radial, an inner or ulnar. Moreover, in the Orang the nerve-supply of these two heads agreed with what is found in Man, but was different in the case of the Gibbon. That is to say, in the Orang the radial head received the median nerve, while the ulnar head was supplied by the deep branch of the ulnar nerve; but the Gibbon presented an exception to this rule, for in it both heads of the muscle were supplied by branches from the median nerve. Bearing in mind therefore the strong support that nerve-supply affords as a key to muscle homologies—a proof, however, which I am by no means disposed to regard as absolute—we are bound to make a closer scrutiny of the so-called inner head of the flexor brevis pollicis, and it is certainly somewhat remarkable that an examination of the four animals under consideration should throw so much light on this point.

In the Gibbon the inner or ulnar head arose deeply in the palm from the ligamentous structures in the vicinity of the trapezium and from the bases of the 1st and 2nd metacarpal bones. The muscle lay in close contact with the shaft of the metacarpal bone of the thumb and was inserted in conjunction with the adductor pollicis.

In the Orang a slender muscular slip, which at one time would have been described as a middle head to the flexor brevis pollicis, was found. This was a perfectly distinct but slender piece of muscle placed in relation to the ulnar border of the shaft of the 1st metacarpal bone, from which it arose—an interosseous primus volaris of Henle, or inner head of flexor brevis pollicis. The insertion of this slip was in conjunction with the adductor muscles.

In the Chimpanzee, instead of a muscular slip, there was a fibrous band in the position of the inner head, while in the Gorilla even this fibrous band had disappeared.

Reducing these facts to a tabular form, they at once become quite clear.

	Gorilla.	Chimp.	Orang.	Gibbon.
Flexor brevis pollicis—(outer head), -	x	x	x	x
Flexor brevis pollicis—(inner head)— (<i>Interosseous primi volaris</i>), -	}	<i>rudimentary.</i>	x	x
Adductor pollicis obliquus, - - -			x	o
Adductor pollicis transversus, - -	x	x	x	x

Such a table shows us that in the Gibbon we find the original condition of parts. In it the flexor brevis pollicis possesses a true inner head, *i.e.*, interosseous primus volaris, and the adductor pollicis has not yet segmented sufficiently to produce an adductor obliquus pollicis or spurious inner head for the short flexor. But the tendency is for the proximal part of the adductor pollicis to separate itself from the rest of the muscle, and move radiad as the spurious inner head of the short flexor, in reality, adductor obliquus pollicis. This condition is well seen in the Orang, and as a consequence of the increase of this spurious inner head, the true inner head has become reduced in size and pressed into a deeper position. A further stage of the same process may be seen in the Chimpanzee, in which the spurious inner head has still further reduced the true head until it is merely represented by fibrous tissue. Finally, in the Gorilla we have the completed process, and the result is that

the true inner head has entirely disappeared, unable to resist the developmental activity of the spurious inner head.

Turning now to the question of nerve-supply, the Gibbon again gives us the original condition, viz., the supply of both heads of the flexor brevis pollicis by the median nerve, and the supply of the adductor pollicis (obliquus et transversus) by the deep branch of the ulnar nerve. In the Orang, however, we find that the true inner head of flexor brevis pollicis—interosseous primus volaris—is also supplied by the ulnar nerve, and this must be explained. Brooks¹ has dealt with this subject in a special paper, and I agree with him in considering that as the true inner head becomes reduced in size by the advancing spurious head (adductor obliquus pollicis), so in like manner the median nerve is displaced by the greater activity of the ulnar nerve. Not only so, but in Man we occasionally find the ulnar nerve in the substance of the outer head of the flexor brevis pollicis. This was the case in a subject dissected for demonstration purposes in the University Anatomy Department during the past winter session. A probable explanation of such a condition is, that the true inner head of the flexor brevis pollicis is not only a meeting-point for the median and ulnar nerves, from which the median nerve is ultimately displaced; but it may also act as a bridge across which the ulnar nerve may travel to reach the outer head of the short flexor of the pollex.

Abductor Minimi Digiti.—In all the animals this muscle was present in a well-developed state, and it possessed the same attachments as are characteristic of the corresponding muscle in Man. Commencing at the pisiform bone, it lay along the ulnar border of the palm, and was inserted into the ulnar aspect of the base of the 1st phalanx of the little finger, closely blended with the insertion of flexor brevis minimi digiti.

Flexor Brevis Minimi Digiti.—As in Man, this muscle possessed only a single head of origin, which was attached to the anterior annular ligament and the hook of the unciform bone. This arrangement was constant throughout the series. The muscle was inserted in common with the abductor minimi

¹ Brooks, *Jour. Anat. and Phys.*, vol. xx., 1882.

digiti, but in addition the Gibbon showed a tendinous prolongation, which was sent forwards to be inserted into the fibrous structures at the distal extremity of the 1st phalanx.

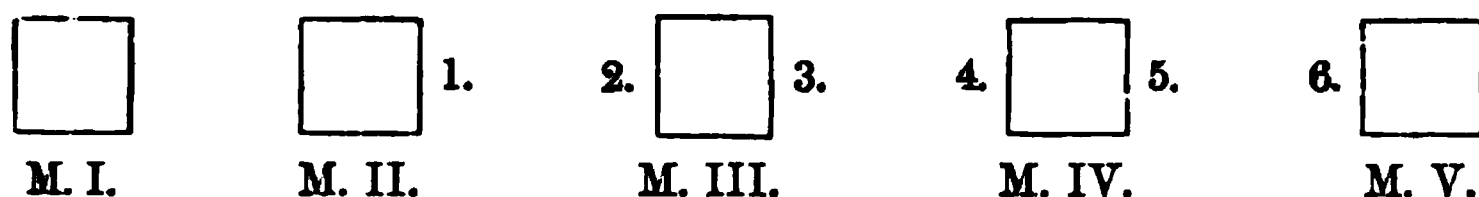
Opponens Minimi Digiti.—In each of the animals the origin of this muscle was similar, viz., from the unciform process of the unciform bone and from the anterior annular ligament. Crossing obliquely inwards, it was inserted into the ulnar border of the shaft of the 5th metacarpal bone. In each case its origin was closely blended with that of the flexor brevis minimi digiti, and together they lay superficial to the deep ulnar nerve and vessels.

Interossei.—This important group of muscles fulfils the functions of adductors and abductors of the digits. In each of the animals the line of adduction and abduction was the same as in Man, viz., the middle digit. Throughout the series the main features of the arrangement which prevails in Man held good here. The mesial plane of the hand was the same; the muscles divided themselves into two groups—an abductor or dorsal group, an adductor or palmar group. Each muscle of the former set arose by two heads of origin; each muscle of the latter set had a single head of origin. Thus, in all of the animals, there were four dorsal interosseous muscles and three palmar ones. In addition to these features, which were common throughout the series, the Chimpanzee presented some points of peculiarity. Viewed from the dorsum of the hand, its dorsal interossei were the same as in the other animals, but looked at from the palm, there were not only the usual three palmar interosseous muscles performing the function of adductors, but in addition there were other three muscles, distinct from the dorsal interossei, performing the function of abductors. Champneys¹ has described these as palmar interossei, thus bringing up the number to six in the Chimpanzee. In my detailed description of these muscles² I have also included them in this group for descriptive purposes, and because they appear entirely on the palmar aspect, but I doubt whether they should be so regarded. The six palmar interosseous muscles are arranged in pairs—one pair in each of the three inner

¹ *Loc. cit.*

² *Thesis*, in Library of University of Edinburgh.

interosseous or inter-metacarpal spaces. Applying to each a numerical name, we may schematically arrange them thus:—



In this way we see quite clearly that 1, 4, and 6 are the usual palmar interossei; while 2, 3, and 5 are the additional muscular slips. Each of these additional muscles has fibres of origin from both of the metacarpal bones between which it is placed. Thus No. 2 arises from the radial side of the metacarpal III. and slightly from the ulnar side of metacarpal II.; No. 3 arises from the ulnar side of metacarpal III. and slightly from the radial side of metacarpal IV.; No. 5 arises from the ulnar side of metacarpal IV. and slightly from the radial side of metacarpal V.

But not only do they resemble dorsal interossei in their two-headed origin; their insertions also place them in harmony with the dorsal muscles; for No. 2 is inserted with dorsal interosseous II.; No. 3 is inserted with dorsal interosseous III.; and No. 5 is inserted with dorsal interosseous IV. I think that additional confirmation of this view may be obtained from Professor Cunningham's¹ description of the dorsal interosseous muscles of *Thylacinus cynocephalus*. After describing the dorsal interossei as seen from the dorsal aspect, he says:—

“If we examine them upon their palmar surfaces after the removal of the palmar and intermediate muscles, we find an accessory slip in connection with each of the three ulnar muscles Two arise from the base of the middle metacarpal bone—one on each side of it—and they are inserted one into each side of the base of the 1st phalanx of the same finger. The third slip arises from the base of the metacarpal of the ring finger, and is inserted into the ulnar side of the base of the corresponding phalanx.”

These three accessory slips which Cunningham found in Thylacine, and which he regards as undoubtedly belonging to the dorsal interossei, seem to me identical with the three

¹ Cunningham, *loc. cit.*

additional muscles which appear in the palm of the Chimpanzee. I am therefore of opinion that instead of describing them as the 2nd, the 3rd, and the 5th palmar interossei, it would be more accurate to regard them as accessory slips to the 2nd, 3rd, and 4th dorsal interossei, for not only does their function place them in this group, but the double-headed nature of their origins and their arrangement in Thylacine also point to the dorsal group as their true position.

On the other hand, we may regard the typical manus as presenting three layers of intrinsic muscles, viz., an adductor stratum (contrahentes); an abductor stratum (dorsal interossei); and an intermediate stratum, consisting of short flexors of the digits, each of which possesses two heads. In the hand of Man and of the Apes, the abductor stratum presents the same general features, but, with the exception of the Gibbon and Chimpanzee, the adductor stratum is so modified that only the adductor muscles of the pollex remain. With regard to the intermediate stratum—the short flexors—various modifications have resulted in the disappearance of certain of these muscles and in the persistence of others which, in Man and the Apes, are described as the palmar interossei. Now, the three additional interossei, seen in the palm of the Chimpanzee, occupy positions which entitle them to be ranked among the short flexors of their respective digits in a typical hand.

Palmaris Brevis.—Notwithstanding that in every case the dissections were conducted with the utmost care, no trace of this muscle could be found in any of the animals examined.

The *Palmar Fascia* had the same general arrangement as in Man. Its central triangular portion was always a well-marked feature, and from the deep surface of this portion, very strong septa sank into the palm, so that the long flexor tendons very soon became confined in tunnel-like grooves. On the flexor aspects of the digits the usual flexor sheath was present and lined by a synovial membrane. Similarly the tendons passing from the forearm into the palm beneath the anterior annular ligament were surrounded by the loose folds of a synovial membrane. The anterior annular ligament was a strong fibrous arch, having the usual attachments to the outer and inner ends of the series of carpal bones.

THE NERVES OF THE SUPERIOR EXTREMITY.

For the reasons previously noted, I was not able to examine the brachial plexus of the Gibbon, but in all the other Apes this plexus was formed by the anterior primary divisions of the lower four cervical nerves and by the anterior primary division of the 1st dorsal nerve. In all there was a loop of communication from the anterior primary division of the 4th cervical nerve. The formation of the plexus was in every case closely akin to that of Man, resulting in the production of three principal cords. That of the Orang (fig. 3) most nearly resembled the human plexus, while that of the Chimpanzee (fig. 2) was somewhat simpler, and that of the Gorilla (fig. 1) rather more broken up, especially as regards the roots of the outer cord. My dissection closely corresponded with the figure given by Eisler¹ in his description of the vessels and nerves of the Gorilla.

The branches from the brachial plexus, both supra-clavicular and infra-clavicular, were nearly identical with those of Man. The individual nerves were wonderfully similar to those of Man in regard to the details of their distribution.

The nerve for the rhomboid muscle was given off by the 4th cervical nerve in the cases of the Gorilla and Chimpanzee,² but in the Orang it arose from the posterior aspect of the 5th cervical nerve.

Unfortunately the nerve to the subclavius muscle was not found in the Orang, but in the Gorilla and Chimpanzee it arose from the junction of the anterior branches of the 5th and 6th cervical nerves. Kohlbrügge³ found this nerve arising from the 6th cervical nerve in the Gibbon.

The phrenic nerve received a small root from the 5th cervical nerve in the Gorilla and Chimpanzee. In the Gorilla this branch passed downwards and inwards to reach the anterior aspect of the scalenus anticus muscle, where it united with the phrenic nerve close behind the subclavian vein.

The *Posterior Thoracic Nerve*—nerve to serratus magnus

¹ Eisler. Das Gefäß und Periphere-Nervensystem des Gorilla. 1890.

² *Loc. cit.* Champneys.

³ *Loc. cit.*

muscle—had the same direction and distribution as in Man, and arose in the Gorilla from C. V. and VI.; in the Orang from C. V. and VI.; in the Chimpanzee from C. IV. V. and VI.

The *Suprascapular Nerve* in the Gorilla differed in its origin from that of the Chimpanzee and Orang. In the Gorilla it sprang from C. IV. and V. before the junction of the latter nerve with C. VI., and so it was also found by Eisler.¹ In the Chimpanzee and Orang it arose from C. V. and VI. In the Gibbon, Kohlbrügge² states its origin from C. V. As regards its distribution it corresponded throughout the series and with the same nerve in Man. It supplied muscular branches to the supra- and infra-spinatus muscles and an articular branch to the shoulder joint. Only in the Gorilla was a suprascapular ligament found, and underneath this band the nerve travelled to enter the supra-spinous fossa.

Anterior Thoracic Nerves—external and internal.—In the Gibbon, Chimpanzee, and Orang, these nerves arose from a common trunk which descended behind the clavicle to break up for the supply of the two pectoral muscles. In the Gorilla, on the other hand, the two nerves were always distinct; the upper or external arising from C. VI. and VII., the lower or internal from C. VII. and the inner root of the median nerve. In the Gorilla and Gibbon it was clearly seen that the one which pierced the pectoralis minor ended in the sternal origin of the pectoralis major, whereas the upper of the two nerves (which did not pierce the pectoralis minor) was entirely distributed to the upper or clavicular origin of the pectoralis major.

The *Subscapular Nerves* varied in number from three to five. They all arose from the posterior cord of the brachial plexus, and they supplied the usual muscular branches. It is of interest to note that the nerve for the teres major—which is a subscapular nerve—arose in the Gorilla from the circumflex nerve, which gave off two branches, one entirely distributed to the subscapularis muscle, and the other partly to this muscle but chiefly to the teres major as just mentioned. A somewhat similar arrangement is occasionally found in the human subject.³

¹ *Loc. cit.*

² *Loc. cit.*

³ W. Turner in *Natural History Review*, 1864, and *Journal of Anat. and Phys.*, vol. vi. p. 104, 1872.

Circumflex Nerve.—This nerve had the same general course and distribution as in Man, and it was similar throughout the series of animals. It gave off its branches to the same parts as in Man, but no ganglionic swelling could be distinguished on the branch to the teres minor. In the Gibbon its external cutaneous branch ran downwards through the substance of the deltoid muscle and appeared at the lower part of the insertion of this muscle to be distributed cutaneously as low as the external condyle of the humerus. A branch with a somewhat similar distribution was found in the Chimpanzee, only it pierced the external head of the triceps instead of the deltoid.

Musculo-spiral Nerve.—In all the animals this was a large nerve, the origin, course, and distribution of which closely corresponded throughout the series and with the same nerve in Man, that is, it supplied branches to the triceps anconeus, supinator longus, and extensor carpi radialis longior muscles, besides cutaneous and articular branches. Wherever the latissimo-condyloideus muscle was present, it derived its nerve-supply from this trunk, showing that the latissimo-condyloideus must be considered as a portion of the triceps, although it takes origin from the tendon of the latissimus dorsi.

Only in the Gorilla were slender filaments of this nerve found entering the external aspect of the brachialis anticus muscle.

In every instance this nerve ended by dividing into radial and posterior interosseous nerves.

The radial was always a cutaneous nerve on the outer aspect of the forearm, and extended to the digits on their dorsal aspect. The amount of digital supply which the radial nerve provided depended on the point of termination of the posterior interosseous nerve. In the Gorilla the radial nerve and the dorsal branches of the ulnar nerve shared the cutaneous supply of the digits equally—two and a half digits each. In the Chimpanzee the radial nerve supplied both sides of the pollex and the radial side of the index, while the posterior interosseous nerve supplied contiguous sides of the index and medius, and thus between them they overtook the supply of two and a half digits. In the Gibbon, the radial nerve supplied both sides of the pollex and the radial side of the index, while the posterior interosseous nerve supplied contiguous sides of the index and

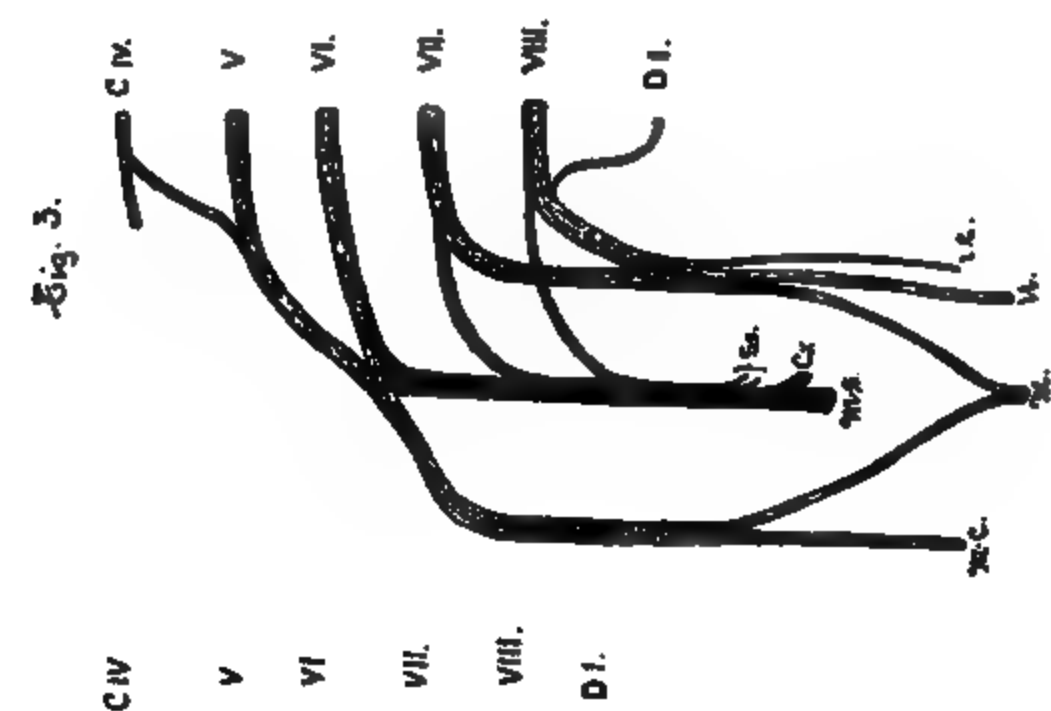


Fig. 2.

C IV
V
VI
VII
VIII
D I

Fig. 1

C IV.
V
VI
VII.
VIII
D I.

medius and contiguous sides of the medius and annularis. Thus between them they supplied three and a half digits.

Although the source of the nerve-supply of skin is never of so much importance as the source of the nerve-supply of muscles, it is interesting to see that the radial and posterior interosseous nerves can take up between them the same amount of cutaneous nerve-supply as may be associated with the radial alone in the case of Man, especially when we remember that both of these nerves are derivatives of the same nerve trunk, viz., musculo-spiral. We may therefore conclude that although at first the posterior interosseous nerve is a mixture of motor and sensory fibres, yet the tendency is for this nerve to become more fully specialised as development advances and greater co-ordination of the muscles of the hand and forearm are required, and consequently the cutaneous nerve fibres become more confined to the radial nerve.

The posterior interosseous nerve supplied the same series of muscles as in Man, except in the Gibbon, where a slender filament quite distinctly passed forwards and pierced the interosseous membrane, to end in the deep surface of the pronator quadratus. In my dissection there was no other source of nerve-supply for this muscle, and of the identity of the muscle there could be no doubt. It is possible that this source of nerve-supply was abnormal even in the Gibbon, but it shows that absolute dependence is not to be placed on nerve-supply as an infallible guide to muscle homology. There was one point in connection with the posterior interosseous nerve of the Chimpanzee which deserves special mention, because it afforded some explanation of the position of this nerve as we find it in Man, embedded in the substance of the supinator brevis muscle. As the nerve passed from the anterior to the posterior aspect of the forearm it was never altogether hidden from view, being merely covered by a very thin aponeurotic fascia on the surface of the supinator brevis, and it can readily be understood how an increase in the size of the muscle and in the number of its fibres taking origin from this investing fascia would cause a submergence of the nerve and produce the characteristic appearance of the nerve piercing the muscle.

Musculo-cutaneous Nerve.—As its name indicates, this was a
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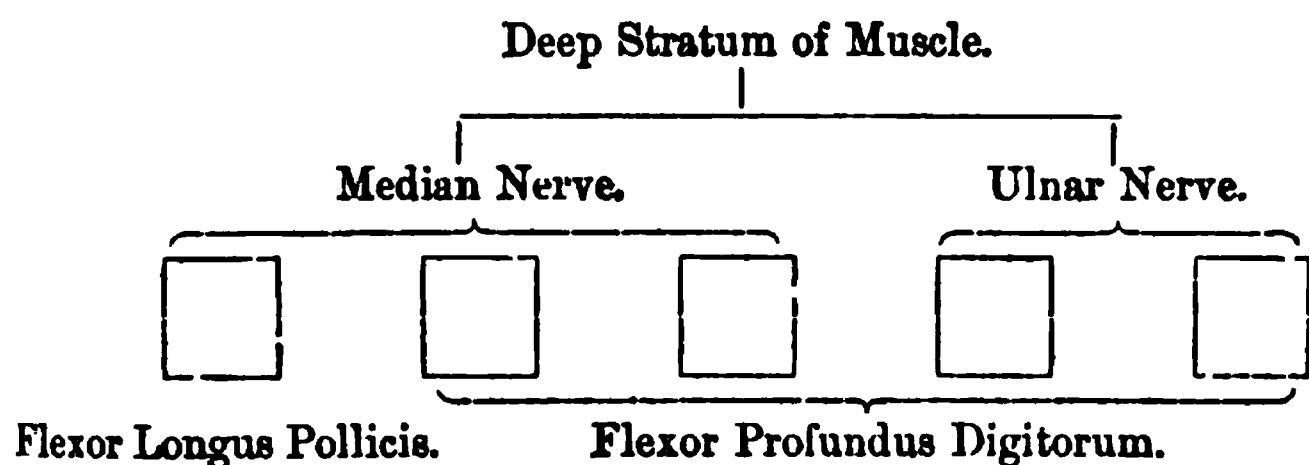
mixed nerve, since it provided motor branches to certain muscles and terminated cutaneously. The muscles which it supplied were those usually seen in Man. It is interesting to note that the branches for the coracobrachialis medius and longus arose separately in the Chimpanzee, and moreover the branch for the lower muscle arose first. In the Gibbon, the musculocutaneous nerve was not so distinctly isolated as in the other animals. After supplying a twig to the coracobrachialis it then gave filaments to the biceps and continued its course on the brachialis anticus. While lying on that muscle it sent twigs of communication to the ulnar nerve and terminated in a long slender continuation as its cutaneous termination. In all the animals these cutaneous branches were distributed on the outer aspect of the forearm, extending as far as the wrist and ball of the thumb.

Median Nerve.—This large and important nerve had many points of similarity with its fellows throughout the series of dissections. In every case it commenced its course external to the axillary and brachial arteries; in all, it passed subjacent to the brachial artery in the lower part of the arm—a condition of parts which has been seen in the human subject; in all, it entered the forearm between the superficial and deep groups of flexor muscles; in all, it was responsible for the same general supply of muscles and skin. But there were points of difference to be observed in the different animals. Thus, in the Gorilla, at the point where the median nerve crossed beneath the brachial artery, viz., in the lower third of the upper arm, it gave off a branch which was joined by one from the musculocutaneous nerve, and together they entered the lower part of the brachialis anticus muscle, and probably reached the elbow-joint. This afforded the only instance of a branch arising from the median nerve above the level of the elbow-joint.

Again, in the Gorilla, Chimpanzee, and Gibbon, distinct branches of communication existed between the median and ulnar nerves as these main trunks lay upon the deep stratum of muscles in the forearm. In the Chimpanzee the nerve formed by communicating branches from median and ulnar gave off a twig for the ulnar segment of the deep flexor and then joined the ulnar nerve. In connection with the study of

the great deep flexor we have already seen that the ulnar segment of the muscle ultimately provided the tendons for the three inner digits, while the radial or humero-radial segment provided tendons for the thumb and index fingers. The nerve-supply of these segments is most interesting. We find that the radial segment is always supplied entirely from the median nerve, either directly, or indirectly through its anterior interosseous branch. The ulnar segment, on the other hand, receives nerve-supply from two sources—(a) the median or its anterior interosseous branch (sometimes both, as in the Orang), and (b) the ulnar nerve. Now, a careful examination shows that the portion of the ulnar segment supplied by the median nerve is readily separable from the rest of the segment, and the tendon which the part in question provides is distributed to the medius digit. Here, then, we have proof that this deep flexor stratum cleaves into two unequal portions so far as nerve-supply is concerned, and muscular substance corresponding with the three radial tendons—(pollex, index, and medius)—is supplied by the median nerve, while the remainder of the muscle for annularis and minimus is supplied by the ulnar nerve. We have already indicated how the increased development and specialisation of that portion of the radial segment, associated with the pollex, causes the remainder of the radial segment to approximate more closely to the ulnar segment, until ultimately it assumes the appearance of an inherent part thereof.

The following scheme will serve to illustrate the transformation and the homologies :—



Coming now to the consideration of the median nerve as distributed in the palm of the hand, we find that in the Gorilla and Orang the cutaneous and muscular supply were exactly

the same as in Man. In the Chimpanzee, the cutaneous supply resembled that found in Man; but in regard to the supply of muscles, it had the 3rd lumbrical muscle supplied by the median nerve, while all the other muscles were supplied just as in Man. The greatest variety, however, existed in the Gibbon. In it the median nerve merely supplied the two and a half radial digits with digital cutaneous branches; and of muscles, it supplied the two outer lumbricales, the abductor pollicis (brevis), the opponens pollicis, and both heads of the flexor brevis pollicis, the latter supply being very distinct.

As already indicated, in discussing the posterior interosseous nerve, there was no trace of any branch from the anterior interosseous (median) to the pronator quadratus muscle of the Gibbon.

Ulnar Nerve.—This nerve commenced its course external to the great vessels of the upper arm, and crossed them superficially to reach the inner side of the limb, along which it descended behind the internal condyle of the humerus to the interval between it and the olecranon process, where it entered the forearm between the heads of the flexor carpi ulnaris. In the forearm it formed communications with the median nerve as already mentioned. In the forearm it supplied the customary branches—articular, muscular, and cutaneous. On entering the palm superficial to the anterior annular ligament, it distributed itself exactly as in Man by dividing into a superficial and a deep part. The superficial part provided the cutaneous supply left blank by the median nerve, *i.e.*, one and a half digits in the Gorilla, Chimpanzee, and Orang, and two and a half digits in the case of the Gibbon. From the deep branch twigs were supplied to all the interossei and contrahentes muscles (including the adductor pollicis obliquus and transversus) to the two inner lumbricales of the Gibbon and Orang; one (the inner) lumbrical of the Chimpanzee; the three inner lumbricales of the Gorilla, which had therefore a double nerve-supply (median and ulnar) for the 2nd lumbrical muscle. We must also note that the inner head of the flexor brevis pollicis of the Orang was supplied by the deep branch of the ulnar nerve. In addition to these palmar branches, the ulnar nerve supplied dorsal cutaneous branches, which were distributed to the back of the forearm in its lower

part, and to those parts of the dorsum of the hand and digits left unsupplied by the radial and posterior interosseous nerves.

In each animal the inner cord, *i.e.*, the lowest part of the plexus, supplied internal cutaneous branches, which had the usual distribution to the skin of the inner aspect of arm and forearm.

In the Chimpanzee there was only one intercosto-humeral nerve, and that emerged from the second intercostal space; but in each of the other animals (Gorilla, Gibbon, and Orang) lateral branches emerged from the 1st and 2nd intercostal spaces, and descended as cutaneous branches to the skin on the inner side of the upper arm, usually extending almost to the elbow-joint.

(To be continued.)

EXPLANATION OF PLATE III.

Fig. 1. Radial view of the hand and lower part of the forearm of the Gibbon (*Hylobates* ?). (The index digit was rudimentary, probably owing to injury.) *a.p.l.*, abductor pollicis longus; *a.p.b.*, abductor pollicis brevis; *e.p.b.*, extensor pollicis brevis; *e.l.p.*, extensor pollicis longus; *d.*, dorsal interosseous I.

Fig. 2. Radial view of the hand and lower part of the forearm of the Gorilla (*Gorilla Savagei*). The lettering bears the same significance as in Fig. 1.

Fig. 3. Palmar surface of hand of Gibbon (*Hylobates* ?).

Fig. 4. Palmar surface of hand of Orang-utan (*Simia Satyrus*).

Fig. 5. Palmar surface of hand of Chimpanzee (*Anthropopithecus troglodytes*).

Fig. 6. Palmar surface of hand of Gorilla (*Gorilla Savagei*). In each of these figures the lettering has the same significance. *a.l.*, anterior annular ligament; *n.ul.p.*, ulnaris profunda nerve; *c.*, contrahentes; *f.l.p.*, flexor longus pollicis; *f.b.p. (o)*, outer head of flexor brevis pollicis; *f.b.p. (i)*, inner head of flexor brevis pollicis; *ad.p.*, adductor pollicis (fig. 3); *ad.ob.*, adductor obliquus pollicis; *ad.tr.*, adductor transversus pollicis; *ab.m.d.*, abductor minimi digiti; *f.b.m.d.*, flexor brevis minimi digiti.

EXPLANATION OF DIAGRAMS IN TEXT.

Fig. 1.	Brachial plexus of Gorilla.
Fig. 2.	„ „ Chimpanzee.
Fig. 3.	„ „ Orang-utan.
C. IV.-VIII.	Cervical nerves (ant. primary divisions).
D. I.	Dorsal nerve.
m.c.	Musculo cutaneous nerve.
M.	Median „
m.s.	Musculo spiral „
Cx.	Circumflex „
U.	Ulnar „
i.c.	Internal Cutaneous „
l.i.c.	Lesser do. „
Ant. Thor.	Anterior Thoracic „
P.th.	Posterior „
S.sc.	Supra-scapular „
S.s.	Sub-scapular „
N. to C.B.	Nerves to coracobrachialis muscle.

CONGENITAL AND SYMMETRICAL PERFORATION
OF BOTH PARIETAL BONES. By D. M. GREIG, M.B.,
F.R.C.S. Edin., *Demonstrator of Anatomy, University
College, Dundee, formerly Surgeon H.M. Medical Staff.*

THE features which render the following case of interest are, firstly, the presence of an extremely rare congenital abnormality; and secondly, the success with which the patient took advantage of the abnormality to practise malingering while serving in Her Majesty's Army. He first came under my notice while serving in India; and subsequently, after my retirement from the Army, and after he had been transferred to the Army Reserve, when he came to me, as I had requested him to do, and put me in possession of the true facts of the case.

R., æt. 25 years, a native of Scotland, a driver in the Royal Artillery, while serving in the Punjab was admitted to hospital in June 1889, complaining of "headaches on the vertex, beating in the eyes, and giddiness on exertion."

Clinical History.—On admission he gave the following history:—He stated that he had always enjoyed exceptionally good health, had never had syphilis, and was a total abstainer. His service had extended over five and a half years, four and a half of which had been spent in India. He referred the commencement of his illness to a fall from his horse. The injury did not produce unconsciousness nor necessitate his admission to hospital. Later on, he began to have pains in his head, often accompanied by attacks of giddiness. He stated that the attacks came on if the weather was very hot or close, or if he had to remain in one position for a long time, as on parade. An attack of giddiness began with beating in the eyes, accompanied by flashes of light, his "whole head swam," and there was frequently ringing in the ears.

Physical Examination.—He is undersized, slightly microcephalic, and has somewhat of a Mongolian type of countenance. On passing the hand over the scalp, a marked flatness is felt in both parietal bones a little in front of the lambdoidal suture. This flatness is due to the presence of two unossified areas—one in each parietal bone—close to its posterior superior angle. The scalp is freely movable over these areas, and the pulsations of the cerebral vessels can be faintly felt. The lambdoidal suture can only be indistinctly felt, but is evidently normal. The sagittal suture is intact, and forms between the perforations a narrow bridge about 2 cm. wide. Each perfora-

tion is nearly circular, and presents a regular, smooth, rounded margin, there being no thickening of the surrounding bone. The right perforation measures in its longest diameter 3·6 cm., and in its shortest diameter 2·7 cm. The left perforation measures in its longest diameter 2·5 cm., and in its shortest diameter 2·3 cm. There is slight tenderness on pressure over both areas, especially over the right one.

Further History.—After having spent the remainder of his period of service in India, and having made every possible use of his abnormality to avoid the performance of duty, he recently returned home “time expired,” and called on me “to let me know the truth about the holes in his head.” He informed me that on the first morning on which he went to hospital his headache was the result of a debauch over night, and that, fearing punishment, he drew the surgeon’s attention to the peculiar formation of his skull. He then took his cue from the questions put to him, and invented the story I have just related.

He now states that the perforations are congenital, and have always been of their present dimensions. They have never given him any trouble, the only inconvenience he has ever experienced from them being that, on firm pressure over either defective area, he feels pain in his head and sees flashes of light in both eyes.

Observations.—Apart from the successful malingering which was practised for nearly three years, this case is specially interesting as being one of those extremely rare examples of congenital and symmetrical perforation of both parietal bones, and appears, moreover, to be the first authenticated instance in which the abnormality has been detected during life. I have been able to discover only three other recorded examples of this rare condition.¹

The first of these examples is recorded by Professor Sir William Turner, who has kindly directed my attention thereto. The calvaria was obtained by Dr T. J. MacLagan, and was figured and fully described by Turner.² It was that of an adult female, whose death had occurred after operation for excision of a congenital cystic tumour of the scalp, situated over the external occipital protuberance. There were present three apertures in this case—one 2·5 cm. by 1·25 cm. in the occipital bone situated in the middle line, and just above the external

¹ *Anthropologie*, P. Topinard, translated into English by Dr R. T. H. Bartley, 1890, p. 207; also *Traité d'Anatomic Humaine*, L. Testut, vol. i. p. 125.

² “On some Congenital Deformities of the Human Cranium,” *Edin. Med. Jour.*, July 1865, p. 133. (For additional cases see Wrany in *Prager Vierteljahrsch.*, 2nd part, 1866.—EDITOR.)

occipital protuberance, and one in the posterior superior part of each parietal bone. Each of these parietal openings was oval in form with the long axis running transversely, that on the right measuring 2.1 cm. by 1.4 cm., and that on the left measuring 1.4 cm. by 1 cm. Dr MacLagan states that in the recent state each opening was closed in by "a cribriform plate of fibrous tissue." The following peculiarities were noticed in relation to these apertures:—(1) The presence of a suture connecting the aperture in the left parietal bone with the sagittal suture; (2) the presence of several very small vascular foramina in the bridge of bone separating the two apertures; (3) the deflection of the superior longitudinal sinus. The groove for the superior longitudinal sinus occupied its normal position until it reached the region where the apertures were situated. It was deflected from the middle line in the interval between the two parietal apertures, and lay along the inner end of the right opening, where it was joined by a groove running from the inner end of the left opening. Maintaining its course to the right of the middle line, it passed downwards close to the right border of the occipital aperture. There are other interesting peculiarities in this calvaria described by Turner, but they have no direct bearing on the present paper. Turner considers the parietal deficiencies as being exaggerated representatives of the parietal foramina, and that numerous veins passed through the fibrous membranes closing these openings. He is led to this conclusion by the position of the openings, the cribriform condition of the membranes closing them, and the grooved state of the parietal bones internally.

M. Broca¹ in a paper on this subject describes a similar abnormality in the skull of a female, a native of the Canary Islands. Near the border of the sagittal suture, and at a distance of 3 cm. from the lambdoidal suture, a perforation existed in each parietal bone. The perforations were symmetrical, regular, and elliptical, each measuring 20 mm. in the long and 13 mm. in the short diameter. The bridge of bone separating these openings was 20 mm. broad, and was divided longitudinally by the sagittal suture into two equal parts. The margins of the openings were

¹ "Sur la Perforation Congénitale et Symétrique des deux Pariétaux," P. Broca, *Bull. de la Soc. d'Anthropologie de Paris*, March 1875.

thick and blunt, and not bevelled on either table. Broca also refers to a similar condition described by Baron Larrey in a skull presented by him to the Val-de-Grâce Museum. The skull was that of a male Spaniard, æt. 36 years, who died of phthisis. The abnormality was only accidentally discovered at the *post-mortem* examination. The skull was normal, but under-developed (microcephalic?), and there was no trace of persistent fontanelles. In the position normally occupied by the parietal foramina were two large symmetrical openings, each measuring 3 cm. in its longest diameter. The edges were blunt and rounded. The osseous bridge between these perforations was very thick, and marked internally by the groove for the superior longitudinal sinus, and externally by the sagittal suture. Each perforation was shaped like a square with the angles rounded off. This case corresponds more closely with mine than does Broca's, both in size and shape of the openings and in the microcephalism.

Sir G. Humphry,¹ in the course of his description of the parietal bone, writes thus:—"The aperture for the vein that runs through the upper and hinder part of the parietal bone into the longitudinal sinus is in some skulls of considerable size. In a specimen in the Cambridge Museum it is large enough to admit the end of the finger." Broca describes a somewhat similar condition in the skull of a negro.² In this case, about 4 or 5 cm. from the lambdoidal suture, were two openings exactly occupying the position of the parietal foramina. In the left one the external opening is 3 mm. wide, whereas the internal opening measures only $1\frac{1}{2}$ mm.; in the right one the external opening is 6 mm., and the internal opening 4 mm. in width. Broca regards this condition as due to an enlargement of the parietal foramen. He further regards the existence of the parietal foramina as abnormal though frequent, and considers the bone as really normal when these foramina are absent. He points out also that each foramen may be replaced by two, three, or four small foramina. This being so, we are provided in the

¹ *A Treatise on the Human Skeleton*, p. 243; see also *Quain's Anatomy*, 1890, vol. ii. part i. p. 86.

² "Sur les trous Pariétaux et sur la Perforation Congénitale double et Symétrique des Pariétaux," P. Broca, *Bull. de la Soc. d'Anthropologie de Paris*, May 1875.

above observations with a series of variations from the normal condition of the parietal bone, of which the ordinary parietal foramen is the commonest, and the cases described above (Turner's, Broca's, Larrey's, and my own) the most exaggerated, examples; while the negro skull described by Broca, and Humphry's case represent the intermediate condition. While, however, an emissary vein may be capable of producing a hole the size of the parietal foramen, it seems doubtful if it could account for the existence of an aperture of the magnitude of those described. But, apart from the presence of the veins, there is nothing to explain the defective ossification of so large an area. Turner's case, indeed, rather implies the existence in these cases of numerous small veins in the situation of the unossified area.

In the discussion which followed Broca's first paper on the subject, Hamy expressed his opinion that the abnormality might have been caused by symmetrical meningo-encephalocele, but there is not the slightest evidence to support such a supposition.

In conclusion, the recognition of this abnormality in the living subject enables us to localise with fair accuracy the underlying portion of the brain. The patient stated that on firm pressure over either defective area he saw flashes of light in *both* eyes. Each aperture appears to correspond in position to a part of the brain lying directly behind the parieto-occipital fissure. With the assistance of Professor D. J. Cunningham's models and Professor Fraser's plates,¹ we are able accurately to localise the portion of the brain underlying the defective area as the anterior part of the corresponding superior occipital convolution, which forms a part of the visual centre.² There appears to be some doubt as to whether this particular area is implicated in the vision of one or both eyes. The statement of the patient that on firm pressure on either area he saw flashes of light in *both* eyes would seem to confirm the view that the superior occipital convolution is concerned in the vision of *both* eyes.

¹ *A Guide to Operations on the Brain*, Alec Fraser, 1890.

² *A Manual of the Diseases of the Nervous System*, W. R. Gowers, vol. ii. p. 19; *The Functions of the Brain*, D. Ferrier, 2nd ed., p. 270; *The Croonian Lectures on Cerebral Localisation*, 1890, D. Ferrier; *A Treatise on Diseases of the Nervous System*, J. Ross, vol. ii. p. 495.

**A SUGGESTION AS TO THE POSSIBLE CAUSE OF
THE CORONA OBSERVED IN CERTAIN AFTER-
IMAGES. By A. E. WRIGHT, M.D. Dubl.**

(From the Laboratories of the Conjoint Colleges of Surgeons
and Physicians, London.)

It is well known that the after-image of a white disk upon a black ground consists of a black central disk upon a white ground, and that this central black disk is seen to be surrounded by a halo or external corona, which is of a more brilliant white than any part of the white surrounding field.

There has always been a question as to how this white corona should be explained. Helmholtz attributed the brightness of the halo to a psychological error of judgment, conditioned by the fact that this portion of the white field of after-image immediately adjoined the black central disk. Hering, on the other hand, is of opinion that its cause ought to be sought for somewhere within the physical, physiological domain. The suggestion which I am about to make is one which is in conformity with this view of Hering.

I would suggest that we have the key to the whole difficulty in the fact that the after-image we are considering is, in reality, not the after-image of any single primary-image (Vorbild), but the resultant after-image of three, or, for practical purposes, we may say two, separate primary images; that is to say, of the primary images of the central white disk upon the black ground which fall upon the retina during three different phases of accommodation—exact accommodation, under-accommodation, and over-accommodation. For practical purposes we may consider the last two images to be identical.

That this is so can be verified by anyone who will observe what takes place in his accommodation during the period of fixation necessary for the production of a distinct after-image. He will begin by accommodating correctly for, let us say, a pencil mark placed in the centre of the white disk as a fixation-

mark, but he will notice that his accommodation will soon begin to flag, and that the pencil mark will grow vague owing to insufficient accommodation. As soon as he notices this, the observer will make an effort to accommodate correctly, with the result that the larger central area which was occupied upon his retina by the diffused image of the white disk, will now become contracted again to the smaller area which corresponds to the retinal image of the disk during correct accommodation, and the diffusion annulus upon the retina of under-accommodation will correspond during the correct accommodation which has supervened to the innermost annulus of the black field. This retinal annulus is, therefore, a debatable zone which, though it ought to be continuously a part of the black field, is thus, by defect of accommodation, being constantly encroached upon by the diffusion circles of the white central disk.

What results from this is in part apparent during the course of the fixation; in part its results manifest themselves in the residual phenomenon of the whole process which, in fact, constitutes the after-image re-stricto sensu.

(1) The phenomena which are observable during the course of the fixation are as follows :—

When either under or over accommodation supervenes we see the central white disk surrounded by a brilliantly white rim, beside which the central portions of the disk appear of a distinctly dull grey colour.

I take it that the bright rim here corresponds to what I have called the debatable zone on the retina, and that its brilliant whiteness is due to a summation of the whiteness of the outermost diffusion circle of the disk which has now come to occupy this zone upon the retina, with an after-image phenomenon, *i.e.*, with the whiteness which is the physiological reaction from the stimulation of this part of the retina by the black light (*sit venia verbo*) of the innermost annulus of the peripheral black field.

On the other hand, the greyness of the central disk is due to two causes—(a) to the absence on that part of the retina of any white after-image phenomenon to summate with it, and (b) to a phenomenon long ago explained by Hering, *viz.*, to the black after-image, which is being suppressed by the white primary.

image, rising above the threshold of consciousness through and even in spite of that repressive influence.

(2) The phenomena which are observable in the so-called after-image proper.

When the repressive strain of the primary-image is taken off, we have to deal with the residual phenomena which constitute the physiological accompaniments of the return of the retina to equilibrium. In this process the white disk, of course, comes out black in the after-image, and the peripheral field comes out white, and then we have the debatable zone to reckon with. It comes out white, because, after all, the distribution of white and black upon the retina during correct accommodation must, of course, condition the broad lines of distribution of white and black in the after-image. The real difficulty, however, comes in when we try to explain why the halo should be the brightest part of the field. I think the explanation of this is to be found in the fact that every after-image phenomenon tends to exhaust itself. By dint of a little perseverance it is not at all difficult to reduce one's retina to the condition in which it can hardly be got to give any after-image response; any lengthy series of after-image observations will do this, and I believe that a ten minutes' fixation would go a good way towards reducing any observer's retina to this condition. The wear and tear come in especially when there is a long spell of stimulation with light of the same colour.¹ Therefore, I take it that the parts of the field that are likely to be soonest exhausted are the peripheral and the central portion, in which stimulation by white is never varied by stimulation with black, or *vice versa*. On the other hand, the debatable zone appears to me to be especially favoured in this respect, as the stimulation with black is every now and then relieved by a momentary² stimulation with white, and an

¹ In connection with this question, perhaps I may make the suggestion here that the reason why green is so restful a colour to the eyes, may perhaps be found in the fact that the eye is being perpetually stimulated by light which, owing to the position of the retinal vessels, must be coloured blood-red before it reaches the retina. The contrast colour would therefore naturally come gratefully.

² It might be argued that alternate stimulation with white and black on any particular portion of the retina would there result in a local condition of retinal equilibrium, corresponding to Hering's "neutral grey," and that an after-image response to such a condition of equilibrium is a matter of plain impossibility.

opportunity is thus afforded for a '*restitutio ad integrum*,' i.e., to a renewed power of after-image response to stimulation with black. I have frequently observed that the halo is particularly well marked after prolonged fixations; but I am quite conscious that in observations of this kind the wish is often father to the fact. I have, therefore, sought to test the hypothesis I have suggested in various ways. I began by making what I thought would prove to be an *experimentum crucis*. I atropinised my eyes in order to eliminate the effects of accommodation, but I found fixation impossible with atropinised eyes, or, at any rate, I found that I could not be sure of the steadiness of my eyes in the many fixations I attempted to make under the influence of the atropin, my power of convergence having become quite disorganised by the paralysis induced in my accommodation.

I then argued that if I removed my white disk and black field to such a distance that accommodation would be practically =nil, I should get after-images which were free from halos. The observations are difficult, inasmuch as a distant object has not sufficient brilliancy to be advantageously used for the purposes of after-images. Very prolonged fixations therefore become necessary, and during these fixations it is difficult to avoid movements of the body, such, for instance, of those accompanying respiration. It is also, of course, evident that movements of accommodation might also be occurring unobserved under these circumstances.

As a result of experiments by this method of distant objects, I could in all cases make out distinct halos to my after-images. According to the suggestion just made, these halos would, however, be attributable to a blurring of the outlines of the retinal image, due to unavoidable movements.

I, therefore, tried another method, and it appeared to me to be a far more satisfactory one. This was to fix the centre spot of my white disk from a distance of about a foot, and to move my

Such an objection would be perfectly valid if the stimulations were equivalent as well as alternate, but on the one hand, it is obvious that the chances are as infinity to one against such an absolute neutralisation of opposite stimulations having completed itself at the precise moment at which the fixation is broken off, and, on the other hand, the approach to a condition of neutral grey on the debatable zone during the course of the fixation is of the very essence of the *restitutio ad integrum* referred to above.

eyes nearer to it and further away from it during the course of my fixation; or, what comes to the same thing, to fix my paper disk upon a long pin and to move it gradually nearer or further away from my eyes by pushing the pin up, or pulling it down, through a piece of black paper which constituted my peripheral field. By this method the debatable zone is evidently enormously increased in extent, and I found that I could by this method obtain a much broader band of halo in my after-images.

I feel inclined to lay a certain amount of stress upon this last observation, as I have verified it so many times that I do not think that it can have been in every case a subjectively suggested phenomenon.

At any rate, I think that this observation justifies me in making the above suggestion as to the causation of the halo.

COMPLETE CERVICAL FISTULÆ: A NOTE ON C. F. MARSHALL'S PAPER ON THE THYRO-GLOSSAL DUCT OR "CANAL OF HIS." By A. A. KANTHACK.

SINCE my return from India I have noticed a paper, by Dr Marshall, on "The Thyro-Glossal Duct" in the twenty-sixth volume of this *Journal*, p. 94. It is not my intention to enter into any controversy, and I am only writing to claim some "consideration" for an account of the formation of cervical fistulæ, which Dr Marshall refuses to give. I have said that a complete median fistula may be due to a tear through the closing membrane of the second branchial groove into the sinus cervicalis. Dr Marshall gives me the credit of this suggestion, but considers my account without "parallel in embryology."

In my paper¹ I referred to Kostanecki's and Mielecki's lengthy paper in Virchow's *Archiv*, to which I was greatly indebted. If this paper had been carefully consulted it would have been found that my assumption was not an original one, but one accepted by such authorities as Rabl, Rückert, Zimmermann, and others. As I cannot here translate, or even extract, the above-mentioned paper, I must again refer to vols. cxx. and cxxi. of Virchow's *Archiv*, where a full account is given of the formation of cervical fistulæ.

It will be found that according to modern embryology, even according to His and Piersol, no *à priori* reasons exist against the assumption made by Kostanecki and Mielecki and myself. Fol, de Meuron, Kastschenko, Liessner, Rückert, and Zimmermann—all of them careful observers—have described an actual tearing (*Durchbruch*) of the closing membrane of the first or second cleft under normal conditions. Rabl, who has studied the sinus cervicalis more specially, lends still greater support to "my" assumption. Finally, reference must be made to Oscar Hertwig's *Text-Book* (third edition, 1890, p. 247), who accounts for cervical fistulæ in the same manner.

¹ The Thyreo-glossal Duct, *Jour. of Anat. and Phys.*, Jan. 1891.
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It is, therefore, not *my* suggestion at all that a complete median fistula may result from a tear through the closing membrane of the second branchial groove into the unobliterated sinus cervicalis; but my explanation of such fistulæ was derived from the works of others, all of them embryologists of a high order. In fine, I must once more ask all those who are interested in the formation of cervical fistulæ to make a careful perusal of the exhaustive paper by Kostanecki and Mielecki.

CONCERNING THE TAXONOMY OF THE NORTH
AMERICAN PYGOPODES, BASED UPON THEIR
OSTEOLOGY. By R. W. SHUFELDT, C.M.Z.S.

FORMERLY the *Pygopodes* were considered by a number of ornithological systematists to be a group of birds containing but one family—the *Colymbidæ*, embracing, in this country at least, all those species known to us as the Grebes and Loons. By some this group was placed in the old order NATATORES, which was created in times gone by, to contain nearly every kind of water-bird, from a Flamingo to an Auk. Even as late as 1839 Brandt¹ included the Penguins in this order, and prior to his day Illiger had associated the Phalaropes with them. Passing by these earlier taxonomies, we find the writers of the later years of the present century removing group after group from this natatorial assemblage, so that at the present time the majority of avian classifiers place in the order Pygopodes only the Auks, Grebes, and Loons. Mr Sclater has committed himself to the opinion that the Pygopodes “seem to form a natural transition between” the Gulls and the Penguins; and to my friend Professor Alfred Newton “it appears questionable whether the Grebes, *Podicipedidæ*, have any real affinity to the two families (*Colymbidæ* and *Alcidæ*) with which they are usually associated, and this is a point deserving of more attention on the part of morphologists than it has hitherto received.”²

Recently the present writer has had occasion to examine into the osteology of all the groups of birds to which reference has just been made, and has arrived at the opinion that the *Pygopodes* constitute a natural suborder of birds, containing only the Loons and Grebes. For the latter I propose a superfamily, *Podicipoidea*, restricting all the species to one family—the *Podicipidæ*; and for the Loons another superfamily—the

¹ *Beiträge zur Kenntniss der Naturgeschichte der Vogel.*

² *Encyclo. Brit.*, 9th ed., vol. xviii., art. “Ornithology,” p. 45.

Urinatoroidea—confining all the species to the family *Urinatoridæ* contained within it. Presently, in the present connection, I shall give the osteological characters which seem to me to distinguish these divisions.

Within the confines of the United States we find no outlying types in her avifauna to the group *Pygopodes* as thus constituted—no bird-forms about which the morphologist has any doubt as to whether they belong to this suborder or not; and I conceive that such forms among other avifaunæ, as we find in the genera *Heliornis* and *Podica*, are too unmistakably stamped with ralline characters, according to recent investigators of their anatomy, to ever be associated again with the Grebes, much less with the Loons.

We have in the United States some six species and subspecies of *Podicipidæ*, and about five species of the *Urinatoridæ*. Several of each of these families are found to range to other parts of the world, as Holboell's Grebe is found in Japan; *Podilymbus podiceps* is found on the waters of the West Indies and the northern half of South America; and two or three of the Loons have a still wider range.

Skeletons of most of these forms have, thanks to the courtesy of the United States National Museum, been in my hands for study, and these supplemented by the material in my own collection have given me the opportunity to examine into the osteology of the entire suborder in North America. Upon comparison and intercomparison of such specimens, I am quite convinced that the *Pygopodes* should be classified as I have suggested above, and that such a classification is a natural one. Loons and Grebes are undoubtedly of a kin, but they are separated by superfamily lines within the suborder to which they both belong. To be used in another connection, I have carefully written out all the osteological characters of agreement as they are found in type species of these two kinds of birds, but the account is altogether of too great a length to be presented here. But I have also drawn up a tabulated synoptical table wherein I show the osteological differences as they are found to exist between the two superfamilies in question, and as that is very much briefer, I make no hesitation in laying it before you.

*The Chief Osteological Characters which distinguish the
Podicipoidea and Urinatoroidea.*

Podicipoidea.—Pars plana ossifies.

Urinatoroidea.—Pars plana does not ossify.

Podicipoidea.—Supra-orbital glandular fossæ but faintly mark the skull.

Urinatoroidea.—Supra-orbital glandular fossæ deeply mark the skull, being within the superior border of the orbit, and separated from each other mesially by a *thin*, longitudinal crest of bone.

Podicipoidea.—Twenty-four or more dorso-cervical vertebræ.

Urinatoroidea.—Twenty dorso-cervical vertebræ, not more.

Podicipoidea.—Sternum *short* and broad, with the lateral xiphoidal processes extending more posteriorly than the mid-xiphoidal piece, which latter is triangularly notched in the middle line.

Urinatoroidea.—Sternum nearly twice as long as it is broad, with the lateral xiphoidal processes not extending more posteriorly than the mid-xiphoidal piece, which latter is unnotched and rounded off posteriorly.

Podicipoidea.—Posterior free extremities of *os furcula* very narrow and pointed.

Urinatoroidea.—Posterior extremities of *os furcula* very broad, laterally compressed, and apices bluntly rounded off.

Podicipoidea.—Posteriorly the ischium does not articulate with the superior margin of the very long post-pubic style, anterior to its free end; and the latter is not perceptibly dilated.

Urinatoroidea.—Posteriorly the ischium does articulate with the superior margin of the very long post-pubic style, anterior to its free end; and the latter is considerably dilated and paddle-shaped.

Podicipoidea.—Pollex metacarpal short.

Urinatoroidea.—Pollex metacarpal remarkably long.

Podicipoidea.—Possessed of a large patella coexisting with an elongated cnemial process of the tibio-tarsus.

Urinatoroidea.—Possessed only of a very small, flake-like sesamoid, which occurs in the tendon of the extensor femoris muscle at its insertion; and probably the true patella has co-ossified in the adult with the elongated cnemial process of the tibio-tarsus.

Affinities of the Pygopodes.

The osteological characters distinguishing the superfamilies indicated are supported by others in other systems of the structural economics of the two groups, but a consideration of them does not fall within the limits of the present paper.

Four years prior to the appearance of Fürbringer's encyclopædic work upon the morphology and taxonomy of birds, or in 1884,¹ I considered the representatives of the extinct genus of cretaceous toothed birds *Hesperornis* to be "powerful divers" and the "ancient ancestors" of our present existing Grebes and Loons. Essentially, this still remains my opinion; and at a later day, after carefully comparing the osteological characters of the *Podicipoidea* and *Urinatoroidea* with the corresponding ones in the skeleton of *Hesperornis regalis* and *H. crassipes*, as given us by Marsh, I again said that the result of those investigations "convince me of the fact that, however widely separated now, our existing Loons and Grebes are derived from the same ancestral stock to which *H. regalis* belonged."²

Our existing Grebes and Loons, according to this view then, are derived from, or are the indirect descendants of, great toothed Divers long since extinct. Possibly the *Hesperornithidæ* were an offshoot family from a superfamily—the *Hesperornioidea*, forms which I picture to my mind as having the power of flight, and being the more typical of those extinct Divers, and from them our present PYGOPODES were derived, but we yet lack the necessary material to place such a question beyond all dispute. From a consideration of the osteological characters, I consider the *Podicipoidea* to be an earlier offshoot

¹ *Proc. U.S. Nat. Museum*, vol. vii. p. 331.

² *Jour. of Anat.*, Lond., Jan. 1890, p. 169.

of the pygopodous stem than the *Urinatoroidea*, and more nearly related to *Hesperornis* than are the latter birds. The morphology of the pelvis and the pelvic limb, as well as certain characters in the skull and trunk skeleton, point in favour of this view, I think. So far as the affinities of the *Pygopodes* are concerned with other groups of existing birds, I have shown in other places that they present a number of osteological characters exhibited in common with the *Alcæ* and the *Longipennes*, more with the first, and more or fewer with the latter group.

**EXPERIMENTAL PATHOLOGICAL EVIDENCE
PROVING THE EXISTENCE OF PANCREATIC
DIABETES.¹ By VAUGHAN HARLEY, M.D., M.R.C.P.**

GREAT difficulties are unfortunately experienced in giving animals artificially pancreatic diabetes, from the fact that all operations on the pancreas are exceedingly fatal. So fatal, indeed, that the mere effects of the operation itself, no matter however carefully and skilfully performed, often cause the death of the animal within a few hours after the operation. While the after-effects of the operation are so prejudicial to life that it is a rare thing for the animal to live more than a month or two—a period of time scarcely sufficient to yield perfectly conclusive results. Notwithstanding these drawbacks, however, the data derived from the artificial production of pancreatic diabetes in animals are not alone of great scientific interest to the physiologist, but of immense practical value to every physician engaged in the treatment of cases of diabetes. Consequently, the facts I am about to adduce cannot fail to instruct, as well as interest, all who are paying attention to the onward march of rational medicine.

Before beginning to give in detail the results of my own researches, it may be well for me to give a brief outline of the experimental facts previously published on the same subject by others. And this I do all the more readily, seeing that the experimental literature of Pancreatic Diabetes is exceedingly limited. Indeed, it only began in 1856 with what Claud Bernard² published regarding the effects of interrupting the flow of the pancreatic juice into the intestines, by blocking up the duct with solid paraffin. As all the animals he operated upon died, he believed that the removal of the pancreas was

¹ The data about to be given were in great part included in the Edinburgh graduation prize thesis, for which I received a gold medal in August 1891. The thesis was entitled "A Clinical and Experimental Inquiry into the Nature, Causation, and Treatment of Pancreatic Diabetes."

² Claud Bernard, "Mémoire sur le Pancreas," &c., *Compt. Rendus*, vol. i., 1856; and "Leçons de Physiologie Experimentale," vol. ii. p. 274, 1856.

an inevitably fatal operation. He noticed that all the dogs experimented upon became thin; that neither were the fatty parts of the food absorbed from the intestines into the blood, nor were all the starchy matters changed into sugar. He, however, makes no mention of having examined the urine for sugar. Many years later Schiff¹ used paraffin in the same manner as Claud Bernard had done; but as the dogs he operated on remained in perfect health, he did not regard the preventing the flow of the pancreatic juice into the intestines as a necessarily fatal operation. Berard and Collin² extirpated the pancreas from various species of animals, and most successfully of all from pigs, which they said could live perfectly well without the gland. Some doubt has, however, been entertained regarding the completeness of the removal of the organ in the case of the pigs, which apparently suffered but little from the operation. It may not, perhaps, be out of place to mention that when Professor Berard in 1857 exhibited to my father, Dr George Harley, the pigs he had operated upon, among them were two such miserably lean ones that as they were passing alongside of the court-yard wall, on which the sun was shining brightly, he said jokingly to Professor Berard that he thought if they got any thinner they would then be sufficiently transparent as not to be able to cast a shadow on the wall!

Though there is nothing said in Berard and Collin's paper about sugar having been either looked for or found in the urines, as extreme emaciation is one of the most notable signs of pancreatic diabetes, it is, I think, not at all improbable that as the pigs my father saw were so exceedingly lean, their urines may have contained sugar.

Klebs and Munk³ extirpated the pancreas in dogs, but as they never found sugar in any of their urines, they considered that when diabetes mellitus occurs in man in association with pancreatic disease, it is due to an implication of the solar plexus. In a footnote, however, to Von Mering's paper, Klebs mentions that they did not remove the whole of the pancreas, so this fact may account for their not finding sugar in the urines of the dogs they experimented upon, as will be afterwards explained.

Finkler,⁴ in his cases of extirpation of the pancreas, in likewise, did not find diabetes mellitus follow upon the operation.

Senn,⁵ in his work on the surgery of the pancreas, says that he found that when he extirpated the whole of the gland from cats and dogs, they only lived from a few hours to nine days. He thus tabulates the causes of the deaths of the animals after the total extirpation of the pancreas :—

¹ Schiff, *Med. Centralb.*, p. 790, 1872.

² Berard et Collin, "Mémoire sur les Effets de l'Extirpation du Pancreas," *Gazette hebdom. de Med. et de Chir.*, vol. v. p. 59, 1858.

³ Klebs and Munk, *Tageblatt. der 43. Versammlung deutscher Nat. und Aerzte*, Innsbruck, 1869.

⁴ Finkler, *Verhand. des Congress für innere Medicine*, Wiesbaden, p. 172, 1886.

⁵ Senn, "Die Chirurgie des Pankreas," Volkmann's *Sammlung Klinischer Vorträge*, Nos. 313-315, Leipzig, 1888.

A dog died in 9 days from peritonitis.					
„	„	„	4	„	„ gangrene of duodenum.
„	cat	„	5	hours	„ hæmorrhage and shock.
„	„	„	1½	„	„ „ „
„	dog	„	4	days	„ suppurating peritonitis.
„	cat	„	2	hours	„ hæmorrhage.

In none of these cases was the operation performed with the view of inducing diabetes, and consequently sugar was not searched for in the urine. Nevertheless, it is well to call attention to the fact that the dog that lived nine days is said, in spite of good feeding, to have lost no less than 2·5 kilos. = 5 lbs. 5½ oz. in weight.

It is also well to direct attention to the fact that a dog which lived 76 days, after a partial extirpation of the organ, was noticed to have developed a remarkable appetite at the end of three weeks, and that the part of the pancreas which had not been removed was found to be atrophied. Another dog which had for the first four weeks remained in comparatively good health began to emaciate in spite of his eating as much as four normal dogs of the same size would have done, and died 126 days after the operation. In this case, too, the remaining portion of the pancreas was found atrophied. Both of these dogs were thought to have continued in good health until atrophy of the remaining portion of the pancreas supervened. In spite of sugar not having been looked for in the urines in these cases, as they lost so much flesh, &c., it is not improbable that they may have been diabetic.

Martinotti¹ extirpated the pancreas almost completely. His observations were, however, solely directed to Lieberkuhn's glands, which he considered after the extirpation of the pancreas took on the functions of that organ. Although he made no examination of the urine, he mentions incidentally that in one dog there was marked faulty nutrition, with great loss of flesh.

It was Von Mering and Minkowski² who first called attention to the fact that complete removal of the pancreas is always attended by a diabetes mellitus, and that, too, of a severe form.

In some of the dogs they experimented upon sugar appeared in the urine as early as from four to six hours after the operation; in others not until the following day. It reached its maximum quantity of from 5 to 11 per cent. in about two days, and continued so until death. No diminution in the percentage of the sugar taking place even when the dogs had received no nourishment. One dog, weighing 8 kilos. = 17½ lbs., fed on bread and meat, passed from 70 to 80 grammes = from 1078 to 1232 grains of sugar daily. The sugar was shown to be grape-sugar from the quantity estimated by Fehling's liquid and the polariscope exactly corresponding.

¹ Martinotti, "Sulla Extirpazione del Pancreas," *Giornale della R. Accademia di Med. dei Torino*, pp. 348 and 383, 1888.

² Von Mering und O. Minkowski, "Diabetes Mellitus nach Pankreasextirpation," *Archiv für exper. Pathol. und Pharmacol.*, vol. xxvi. p. 371, 1890.

All the diabetic dogs had great thirst, and some were so hungry as to eat even their own faeces. Polyuria was a marked symptom, from 1000 to 1700 c.c.—that is to say, from about 2 to $3\frac{1}{4}$ pints—of urine being voided daily. In spite of good feeding a rapid loss of flesh and great feebleness occurred in all those dogs which lived as long as three weeks. Some being too weak to be able to walk.

In the urine of the dogs were found acetone, aceto-acetic acid, and β -oxybutyric acid. At first there was only sufficient acetone present to render it detectable by Lieben's and Legal's tests; but just before the animals died it had sufficiently increased to be recognisable by the chloride of iron test alone.

Von Mering and Minkowski, I believe, justly assert that this form of diabetes is the direct consequence of the removal of the pancreatic gland itself, and not due to the injury caused to the nervous system by the operation, for they never could discover at the autopsies any evidence of injury to the nerves. In order to test the matter properly (although the fact had been further confirmed by Recklinghausen in the case of a dog he examined) they separated the pancreatic gland entirely from the mesentery, and left it merely attached to the duodenum. Consequently, quite as much injury was done to the nerves near it as if the organ had been extirpated. Nevertheless, there was no diabetes. Again, in two other dogs they applied a double ligature to the pancreatic duct, and likewise separated the pancreas from the duodenum, so that the gland remained only connected with the mesentery. Yet neither of the dogs became diabetic, although one of them had a transitory glycosuria, which they thought might have been probably due to the mere temporary interference with the pancreatic circulation due to the operation.

That a partial extirpation of the pancreas is not followed by diabetes is proved by the following experiments:—In a dog they separated the horizontal part of the pancreas, leaving only the vertical, and no diabetes occurring within the next three weeks, they removed the vertical portion of the gland. Immediately afterwards the animal became diabetic, and remained so until its death, from lung disease, 20 days after the diabetes set in. In another dog they removed the middle part of the pancreas, and, again, no diabetes followed until a month later, after the rest of the gland had been removed.

Heyden¹ completely removed the pancreas from dogs, and in all found diabetes within from one to two days after the operation. In one case, after the dog had passed sugar for 16 days, a whole month elapsed in which no sugar could be found in the urine, although it was during the whole time on the same diet—bread and meat; then the sugar returned, and continued until its death.

In several of his cases the sugar disappeared from the urine shortly before the death of the dog, which is a point of great interest, as a similar thing has been frequently noted in patients suffering from diabetes, associated with disease of the pancreas. He also found

¹ Heyden, "Extirpation du Pancréas et Diabète," Soc. de Biologie, Paris, Oct. 25, 1890, and *Arch. Méd. Exp. et d'Anat. Pathol.*, vol. iii. p. 44, 1891.

acetone and β -oxybutyric acid in urine of dogs rendered diabetic by extirpation of the pancreas, as is met with in the human subject.

Professor Lépine¹ of Lyons substantiated the fact that removal of the whole of the pancreas in dogs is followed by diabetes mellitus.

These being briefly all the experimental facts I have found recorded, I will now cite the results obtained from my own experiments, which were performed in the Physiological Institute of Christiania, under the eye of Professor Sophus Torup, who kindly aided me in every way in his power.

As the anatomy of the pancreas of the dog is quite different from that of the human being, in order that the modes of experimenting may be readily understood, it is necessary to explain that the organ in the dog consists of two almost separate portions, joined together at the head.

One, a duodenal or vertical portion, with its extremity lying in the mesentery, quite away from the intestine, running in close connection with the duodenum, and then joining with the other horizontal portion to form, as it were, the head of the gland, opposite the junction of the stomach with the duodenum. It receives its blood-supply from the pancreatico-duodenal vessels. The subgastric or horizontal portion is longer than the duodenal. It runs from the point of union of the two parts of the pancreas below and somewhat behind the stomach, as far as the spleen. It then turns downwards and ends in a mesentery of its own, on the level of about the middle of the left kidney. In this horizontal portion the splenic vessels run, and in extirpating it, it is necessary to separate them from the gland substance. To all the animals I gave a hypodermic injection of atropine and morphine, about half an hour before performing the operations, while the animals were always kept under the influence of either chloroform or ether during the operation. In all cases the strictest antiseptic precautions were taken, the instruments being always freshly boiled, and kept in a carbolic acid solution until used; while the peritoneal cavity was always washed out after the operation with a freshly-prepared 2 per cent. boracic acid solution, after it had been likewise freshly boiled. In order to avoid unnecessary repetition, I will here, once and for all, describe the mode of operating, which was

¹ Lépine et Barral, *Compt. Rendus*, p. 1314, No. 25, Paris June 25, 1890.

strictly followed in all cases, except in those where it is specially noted to the contrary.

The skin of the abdomen was shaved, and then well washed with corrosive sublimate solution, the rest of the body being kept covered with antiseptic cloths. An incision was next made from the xiphoid cartilage downwards for about 3 or 5 inches in the middle line. The duodenum was now drawn forward, and the pancreas separated from its intestinal attachments. Its vessels were double ligatured. The horizontal or subgastric portion was got at by raising the spleen and great omentum.¹ The splenic vessels were separated as much as possible from the gland tissue, and all the branches going to the gland double ligatured. The pancreas, thus isolated, was removed by merely cutting it out. Having extirpated the organ, the peritoneal cavity was well washed out with hot boracic solution, the wound closed, and dressed with iodoform and collodium.

Total Extirpation of the Pancreas in Dogs.

Experiment I.—A large dog, weighing 18·7 kilos. = 40 lbs., after the removal of the pancreas, was placed in a cage for collecting its urine. On the following morning the wound looked healthy, and he seemed very well. One hundred c.c. of urine had been passed, which both reduced Fehling's solution and fermented with yeast, consequently it contained sugar. He was given some milk. The day after he was very quiet, and took no notice on being patted. His urine still contained sugar. He died 46 hours after the operation.

Autopsy an hour later. Wound looked healthy. The peritoneal cavity contained 50 c.c. of a brownish-coloured fluid. Peritoneal surface both of intestines and mesentery was injected, with here and there small hæmorrhages. The pancreas was found to have been entirely removed. Liver congested, with a large quantity of bile in the large ducts as well as in gall-bladder. Kidneys somewhat congested. The bladder contained 30 c.c. of high-coloured, cloudy, acid urine, which gave a well-marked reduction with Fehling's solution, and fermented. It contained 2 per cent. of sugar, but neither albumen, blood, bile acids, nor bile pigment. However, on adding to it a saturated solution of zinc chloride and ammonia, it gave a distinct urobilin reaction. Urobilin was also proved to be present by a spectroscopic examination; this might be accounted for by the peritonitis.

¹ As I had found, at Professor Dastre's suggestion, when making biliary fistulæ at the Sorbonne in Paris, that it simplified the operation if the omentum was ligatured, and completely removed, I adopted this same plan in my operations on the pancreas.

Here, then, we have evidence of 2 per cent. of sugar being excreted in the urine within 16 hours after complete removal of the pancreas, and, in spite of a peritonitis having developed, continuing until the death of the animal, 46 hours after the operation.

Experiment II.—From a dog, weighing 11 kilos., the pancreas was completely removed; there was great difficulty in detaching the gland from the duodenum. The following day the dog, although somewhat quiet, appeared pretty well. Fifty c.c. of acid urine had been passed in the night; it contained 1·5 per cent. of sugar. The next day the dog was found dead in his cage. No more urine had been passed.

Autopsy.—Peritoneal cavity seemed healthy. Over 1½ inches of the duodenum, a little below the pylorus, was of a dark purple colour, evidently a commencing gangrene. Pancreas entirely removed. Liver, spleen, and kidneys normal. The bladder contained 2 c.c. of urine, which gave sugar reactions.

Here, again, we see that there was an excretion of sugar within 20 hours after the removal of the pancreas.

Experiment III.—Removed the pancreas from a dog weighing 13 kilos. The vessels being very short, and the pancreas closely bound down to the duodenum, I had some difficulty in separating the duodenum from the gland. On the following day the dog seemed well. He had not been put into the cage for collecting urine, it having been thought that he might quicker recover from the effects of the operation if allowed to remain in his kennel. On the second day he was so well that a little milk was given to him. On the third day he was quieter, but still took milk readily. Passed in 24 hours 200 c.c. of a clear acid urine, containing 1·08 per cent. of sugar; no albumen. He was no better the next day. Urine (170 c.c.) acid somewhat darker coloured, contained 2·15 per cent. of sugar; no albumen. He died on the morning of the fifth day after the operation, having passed during the night 55 c.c. of urine, containing 3·10 per cent. of sugar.

Autopsy.—No pancreas remained. Peritoneal cavity appeared healthy. Liver and spleen normal. Kidneys somewhat congested. Middle third of duodenum of a dark purple, almost black colour, but no signs of peritonitis visible. Bladder contained 8 c.c. of pale, acid urine, which gave a copious precipitate on boiling with Fehling's solution.

Here we see that, not only an excretion of sugar took place after the removal of the pancreas, but that there was a steady increase in the quantity excreted, in spite of the dog practically receiving no nourishment. Seeing that he never had more than a cupful of milk in the course of 24 hours.

Experiment IV.—Pancreas extirpated from a dog weighing 10 kilos. The next day the dog remained very quiet. Had only passed

10 c.c. of urine during the night. It contained sugar. During the following night he died.

Autopsy.—No trace of pancreas remained ; nothing else was found abnormal. No urine in the bladder. The only possible cause of death seemed to be the shock of the operation. He died 28 hours after it.

In some other experiments the dogs died too soon after the operation to get enough of urine to be able to say if it contained sugar or not. However, the above experiments are sufficient to show that sugar appears in the urine within 24 hours after the complete removal of the pancreas from dogs, in spite of their receiving no nourishment, and that the quantity of sugar excreted is distinctly progressive up till death.

That the operation itself is a most fatal one, will be seen by the following table, in which is given the results of the eight experiments of complete removal of the pancreas I performed:—

Total Extirpation of the Pancreas in Dogs.

No. of Experiment.	Animal's Weight in Kilos.	Quantity of Sugar in Urine.	Animal Lived.	Supposed cause of Death.
VIII.	12·3	No urine passed.	$\frac{1}{2}$ hour.	Shock.
VII.	12·0	" "	4 hours.	"
IV.	10·0	Sugar present.	28 "	"
VI.	14·5	No urine.	6 "	" + hæmorrhage.
V.	13·5	"	8 "	Hæmorrhage.
I.	18·7	2 per cent.	46 "	Peritonitis.
II.	11·0	1·5 per cent.	40 "	Gangrene.
III.	13·0	1·08–3·1 per cent.	5 days.	"

It was clearly ascertained that the sugar excreted by the dogs, after extirpation of the pancreas, was true grape-sugar, and not maltose. I will cite one case proving this fact.

In the urine of the dog in the case of Experiment II. the quantity of sugar estimated by titration was 1·47 per cent., and the quantity of sugar estimated by polarisation was 1·5 per cent. These figures being so near, show that it was true grape-sugar that was in the urine, and not maltose.

The cause of death in the above cases, as is seen, was much the same as in those where Senn removed the gland, except that I found hæmorrhage less frequently fatal than shock.

Destruction of the Pancreas in Rabbits.

The anatomy of the pancreas in rabbits is entirely different from what it is in the dog, inasmuch as the organ extends over a far greater area, in consequence of its spreading out into a number of fine ramifications in the mesentery. Consequently the rabbit's pancreas presents insurmountable anatomical difficulties in the way of its removal by the knife. This being the case, I destroyed it bit by bit with the galvanic cautery, touching each little branch of the gland separately; and the small hæmorrhages that threatened during the procedure were stopped in the same way.

Experiment IX.—A rabbit, weighing 1894 grammes, was anæsthetised with ether, and the pancreas destroyed in the manner described by the galvanic cautery. No urine had passed on the following day, but on the next day 30 c.c. of urine was obtained. The urine was acid, and contained no albumen; but sugar was detected in it by means of Fehling's solution and yeast. On the third day 15 c.c. of urine was obtained, which contained 1·6 per cent. of sugar. The rabbit died in the afternoon.

Autopsy.—Abdominal wound healthy and firmly closed. On opening the abdominal cavity, an acute peritonitis was discovered. The cause of it was found to be a perforation in the duodenum, 3 inches from the pylorus, of about the size of a threepenny piece, through which the intestinal contents had entered the peritoneal cavity. The perforation was probably caused by the galvanic cautery having injured the peritoneal coat of the duodenum, and led to a perforating ulcer. No pancreas could be recognised on a careful examination.

Thus, we have sugar appearing in the urine of a rabbit, after the destruction of its pancreas, the same as in the dogs. The animal had in the four days lost 279 grammes in weight, notwithstanding that he had as much bread and water as he could eat.

Experiment X.—In a large rabbit (under ether), weighing 2327 grammes, the pancreas was destroyed with the galvanic cautery. The next morning, as he seemed tolerably well, he was given bread and milk, which he immediately ate. Four hours later he was found lying on his side, and soon after died. No urine had been passed, but the bladder contained 50 c.c. of acid urine, which gave the sugar reaction both with Fehling's solution and yeast. The quantity of sugar, estimated by titration, was found to be 1·412 per cent.; the quantity of nitrogen, estimated by Kjeldahl's method, being 0·5712 grammes. No albumen was present.

Autopsy.—Wound healthy. Found commencing adhesions around parts destroyed by galvanic cautery. There appeared to have been

no pancreas left. All the other organs seemed healthy. No hæmorrhage, so the death was supposed to have been due to shock—at least, no other cause for it was discoverable.

Experiment XI.—A rabbit, weighing 1882 grammes, while under ether, had its pancreas destroyed by the galvanic cautery. The following day it was so well as to take milk. The urine passed during the night was unfortunately lost. On the second day 83 c.c. of acid urine were collected. They contained no albumen, but 1·5 per cent. of sugar; the quantity of nitrogen found by Kjeldahl's method being 1·7196 grammes.

On the third day, although it drank milk, it would eat nothing. Forty-three c.c. of acid urine were obtained, containing 1·7 per cent. of sugar and 0·6239 grammes of nitrogen; fourth day, 83·5 c.c. of urine, containing only 0·5 per cent. of sugar, while the nitrogen was still 0·4210 grammes. The urines of the next three days were useless, owing to their having got mixed with milk. I, therefore, now only gave it water, greens, and bread. On the eighth and ninth days the urine contained only traces of sugar. The rabbit had then lost 62 grammes in weight, although it had been feeding well for the last four days. The urine was tested from time to time for sugar after this, but always gave negative results. The animal lived for 61 days after the operation; and from its having died during an excessively cold night (Norway being exceptionally cold), and being greatly emaciated (having lost 737 grammes, nearly half its weight, and that, too, notwithstanding it had for some time been taking food remarkably well), its death was attributed partly to the effects of cold.

Autopsy.—Liver, spleen, and kidneys normal; but of the pancreas no glandular tissue could be recognised, although, I think, there might have been some remnants of the pancreatic tissues left here and there that were undetectable among the many adhesions. Throughout the body were marked signs of emaciation, no fat being recognisable anywhere. Muscles very lax. The urine found in the bladder contained no sugar. The fact of the sugar having only been met with, to any marked extent, in the animal's urine during the first four days after the operation, and none subsequently to the ninth, while the emaciation was markedly progressive, (as great emaciation is often met with in the human subject suffering from pancreatic disease without there being any concomitant diabetes) the question naturally arises, may this not be due to a sufficiently large portion of the pancreas being left healthy, and thus prevent the occurrence of the diabetes, though there may not be sufficient of the pancreatic gland in a normal condition to prevent the emaciation?

If, then, some of the pancreas was accidentally left intact in this case, it is quite possible that it might yet have been insufficient at first to split up or destroy the sugar (in the manner I shall explain in another paper), and hence the diabetes. But that, later on, when the immediate effects of the shock had passed off, the portion of the pancreas left was quite sufficient to prevent the diabetes. It will

be presently shown that a very small portion of the gland is all that is necessary to prevent diabetes occurring.

The great wasting might also be explained by the ducts having been destroyed along with the greater part of the gland, and that, as a consequence, little or no pancreatic juice entered the intestines to aid in the proper digestion of the food and render it fit for assimilation.

I am somewhat doubtful, however, of the above opinion that some of the gland remained is the correct explanation of the fact, as it has been before stated, Heyden found that sugar disappeared for a time from the urine of some of the dogs he experimented upon, notwithstanding that none of the pancreas was left remaining. And I have, I think, a more plausible explanation to give of this fact in a paper on the pathogenesis of diabetes now in hand.

Experiment XII.—Destroyed in a rabbit, weighing 2300 grammes, the whole of the pancreas with the galvanic cautery while it was under the influence of ether. It was found dead on the following morning, but fortunately 42 c.c. of pale urine had been collected and it contained 0·314 per cent. of sugar.

Autopsy.—No pancreatic tissue was detectable, and no other cause of death than supposed shock was recognisable.

The subjoined table represents the results obtained in these four experiments on rabbits:—

Total Destruction of the Pancreas in Rabbits.

Experiment.	Weight of Animal in grammes.	Sugar in Urine.	Lived.	Cause of Death.
XII.	2300	0·31 per cent.	16 hours	Shock.
X.	2327	1·412 „	22 „	„
IX.	1894	1·6 „	8 days	Perforation.
XI.	1882	1·7 „	61 „	Marasmus + extreme cold.

We see, then, that the total destruction of the pancreas in rabbits causes diabetes, just as it does in dogs, and that the sugar in their urines is likewise grape-sugar and not maltose, as was shown in that of Experiment IX., in which the—

Sugar estimated by titration = 1·615 per cent.
„ „ polarisation = 1·520 „

I now come to the consideration of another set of experiments on the pancreas, viz., those performed with the view of ascertaining the effects of its partial destruction on sugar excretion.

Partial Destruction of the Pancreas in Dogs.

In the following two cases only did I think it necessary to merely remove portions of the pancreas, as it had been already done with negative results by Von Mering, and the results I obtained were exactly the same.

Experiment XIII.—In a dog, weighing 10 kilos., the pancreatic duct was doubly ligatured, and the duodenal portion, as well as the head of the gland, removed. None of the urine collected after the operation contained sugar. The dog died in 26 hours.

Autopsy.—Liver, kidneys, and spleen appeared normal. The subgastric portion of the pancreas only remained, and it was of the normal colour. The bladder contained 10 c.c. of acid urine, which neither gave a reduction with Fehling's solution nor fermented with yeast.

Experiment XIV.—From a dog, weighing 12 kilos., the subgastric portion, with the head and duct of the pancreas, were removed. Though the dog lived five days, the urine never contained a trace of sugar.

Autopsy.—All the abdominal organs seemed healthy. Only the duodenal portion of the pancreas remained. The animal died of pneumonia.

In both of these cases, although the different ends of the gland were removed along with the head and the common duct, and no pancreatic juice could find its way into the alimentary canal, there was yet, as we see, no diabetes.

I will now cite two cases in which the greater part of the pancreas was rendered perfectly useless, although it was not removed.

Experiment XV.—The pancreatic duct of a large dog, weighing 23½ kilos., was doubly ligatured, and the portion of the gland lying between the ligatures excised. The remainder was then all, except the subgastric part, isolated by ligatures. On the following day the dog was very quiet, did not even so much as move. In the evening she died; that is to say, in a little over 30 hours after the operation.

The amount of urine collected during this time was 300 c.c.; it had an acid reaction, but contained neither sugar nor albumen.

Autopsy.—There was a little blood-stained fluid in the abdominal cavity. The part of the pancreas which was so completely isolated by the ligatures that it had no connection with the circulation whatever, and consequently, for all practical purposes, was as useless as if it had been entirely removed from the animal's body, was found to have a dark purple colour. While the left end of the subgastric portion, which formed less than one-eighth of the whole gland, was of perfectly normal appearance, and had presumably continued to per-

form the function of sugar destruction. To this fact I attribute the absence of sugar from the urine.

As all the other organs were apparently healthy, the death of the dog was thought to be due to the shock of the operation.

Experiment XVI.—A dog, weighing 20·9 kilos., was operated on exactly as in the preceding experiment, only a very small portion of the subgastric portion of the pancreas being left—certainly not more than a piece the size of a nut. The urine collected in the first six hours contained 0·046 per cent. of sugar, while the urine collected on the following morning gave no sugar reaction at all. The dog died 42 hours after the operation.

Autopsy.—All the pancreas that had been included in the ligatures was of a dark purple colour. The free tip of the subgastric portion alone being of normal appearance. The upper one-third of the duodenum was somewhat darkish, as if it were in a state of commencing gangrene. The bladder contained 2 c.c. of urine, which had no sugar in it.

Experiment XVII.—On a dog, weighing 12 kilos., the operation was somewhat modified. This time the main duct of the pancreas being doubly ligatured, and the portion lying between the ligatures removed. The end of the duodenal portion of the gland was then also removed, and the main artery supplying the subgastric portion ligatured.

On the following day the dog seemed well, and 225 c.c. of a pale yellow urine were collected, which contained traces of sugar, the amount of nitrogen by Kjeldahl's method being 2·097 grammes. On the second day, 160 c.c. of high-coloured urine were collected; but, contrary to the specimen of the day before, it contained no sugar. The nitrogen amounted to 2·437 grammes. On the third day the dog was exceedingly quiet, and could not be induced to eat. He died in the afternoon, having passed 220 c.c. of a high-coloured urine, which, like that of the previous day, was totally devoid of sugar. The urine contained urobilin, as in Experiment I.

Autopsy.—There was a very diffuse peritonitis. The various abdominal organs were somewhat congested. In the part of the pancreas that remained were a few small abscesses, from the size of a pin's-head to that of a pea.

For the sake of easy comparison, I again represent the results obtained in these cases of partial removal, or destruction of the pancreas in the dog, in a tabular form :—

[TABLE.]

Partial Removal or Destruction of the Pancreas in Dogs.

No. of Experiment.	Animal's Weight in Kilos.	Sugar in Urine.	Lived.	Cause of Death.
XIII.	10·0	No sugar.	26 hours.	Shock.
XV.	23·5	"	30 "	"
XVI.	20·9	In first six hours 0·04 per cent. ; no sugar found afterwards.	42 "	Gangrene.
XVII.	12·0	Traces at first ; none afterwards.	3 days.	Peritonitis.
XIV.	12·0	No sugar.	5 "	Pneumonia.

From this we see that the cause of the dogs' deaths in the partial is very much the same as in the total removal of the pancreas. In two of the cases there was, immediately after the operation, sugar in the urine, though none afterwards. The presence of the sugar immediately after the operation might possibly be accounted for by the chloroform used ; but as very little chloroform is needed in dogs first narcotised with morphine and atropine, I cannot regard this idea as being a valid one. It is far more probable, I think, that the manipulations necessary in the operation so disarranged the part of the pancreas that remained, that its sugar-destroying function was for a short time put in abeyance, while, so soon as it had recovered from the effects of the operation, it was again able to carry on its sugar-destroying function, and hence no more appeared in the urine.

Partial Destruction of the Pancreas in Rabbits.

I will only cite two cases in full, and give the others in a tabular form, as the results obtained corresponded exactly with those obtained from the dog.

Experiment XVIII.—Destroyed the greater part of the pancreas of a rabbit, weighing 1672 grammes, with the galvanic cautery. On the following morning 15 c.c. of urine were collected, which contained no sugar. Nitrogen was found to be 0·4587 grammes. He was then given bread and milk. In the next four and twenty hours 42 c.c. of acid was obtained. Like that of the previous day, it contained no sugar ; the quantity of nitrogen excreted had now risen to 0·5374 grammes. During the following night the animal died.

Autopsy.—No apparent cause of death could be found. The part of the pancreas that remained seemed normal.

Experiment XIX.—The greater portion of the pancreas was destroyed in a rabbit, weighing 2160 grammes, in the same manner as in the above. The following day the 10 c.c. of urine collected contained 0.3412 grammes of nitrogen, but no sugar. On the next day 28 c.c. of urine collected, likewise contained no sugar. The rabbit was fed on ordinary vegetable diet, and although the urine was tested daily, as no sugar was ever found in it, the animal was killed on the tenth day. It had lost 304 grammes in weight.

Autopsy.—The greater part of the pancreas, together with the main duct, seemed to have been entirely destroyed. But here and there were found perfectly healthy parts of gland-tissue. The animal's loss in weight was probably due to the absence of the pancreatic juice from the alimentary canal, and the consequent imperfect digestion; while the absence of sugar from the urine may be accounted for by sufficient glandular tissue having been left to destroy the sugar in the blood.

Partial Destruction of the Pancreas in Rabbits.

No. of Experiment.	Weight in grammes.	Sugar in Urine.	Lived.	Cause of Death.
XX.	1361	None.	6 hours.	Shock.
XXII.	1365	"	10 "	"
XXI.	2365	"	8 "	Hæmorrhage.
XVIII.	1672	"	8 days.	Unknown.
XIX.	2160	"	10 "	Killed.

Another series of the same kind of experiments was performed on cats with precisely similar results.

The conclusions I draw, from these and all the other experiments I carried out on the same subject in the Physiological Institute of Christiania, may be briefly summed up as follows:—

1st. Diabetes mellitus is invariably produced in dogs, cats, and rabbits when the pancreas is completely removed, or rendered totally incapable of functioning.

2nd. If only a small portion of the healthy gland is left intact, no diabetes whatever occurs. From its requiring but a very small portion of healthy pancreas to destroy or transform the sugar normally existing in the blood, and thereby prevent the occurrence of diabetes mellitus.

3rd. The mere ligaturing of the ducts of the pancreas is not

followed by the appearance of sugar in the urine, until the obstruction has had time to bring about an atrophy of the secreting cells of the gland. From which it may be inferred that the diabetes produced has nothing whatever to do with the mere stoppage to the entrance of pancreatic juice into the intestinal canal.

4th. The appearance of sugar in the urine, after extirpation of the pancreas, is in nowise due to the injury done to the nerves during the operation, but solely to the total arrest of the pancreatic functions.

Having thus, as I think, clearly shown that a true diabetes mellitus can be artificially induced in dogs, cats, and rabbits, I may now add that a knowledge of this fact, coupled with its interpretation, is of great practical importance to the physician, seeing that the symptoms and signs of the disease as manifested in these animals are in all respects identical to those met with in the severer and always fatal forms of diabetes in man. To wit, polyuria, polyphagia, polydipsia, and rapid emaciation, with extreme muscular weakness. And that, too, as in man, being not unfrequently associated with the appearance in the urine of acetone, aceto-acetic acid, and β -oxybutyric acid (the result of excessive protoid destruction), and the attendant fatal coma. These facts thus afford us additional proof of the immense value of experimental research in the elucidation of morbid phenomena.

THE REPAIR OF BONE, WITH SPECIAL REFERENCE
TO TRANSPLANTATION AND OTHER ARTIFICIAL
AIDS. By A. N. M'GREGOR, M.D., Glasgow.¹ (PLATE IV.)

THE subject of this article is of importance both to the anatomist and to the surgeon: to the former, because the minute anatomy of the processes of repair, and the origin of these processes, are still regarded as uncertain; and to the latter, because an intimate knowledge of the means which Nature employs in the repair of bone lesions is necessary to one whose endeavour is to facilitate recovery. This twofold interest has stimulated researches which have elicited most important discoveries, particularly as to the vitality of bone and of periosteum. We now know that these structures are capable of living after transplantation, and that they exercise the function of bone production in their new position.

Surgeons have made use of this information, and have transplanted bone to repair lesions where the natural processes have failed. There are, however, some points of doubt as to the behaviour of the transplant and its value as a bone producer.

With the object of adding to our knowledge of the subject, particularly with regard to the above-mentioned points, the author performed a number of experiments, the details of which and the results are embodied in this paper.²

The most interesting features of a pathological museum are the new formations and results of reparative processes which have arisen to restore the functions of diseased parts. In lesions of the osseous system these changes are very remarkable for their frequency and extent.

Professor Buchanan's Museum in the Western Infirmary of Glasgow contains a unique specimen of compound double fracture of the femur [No. I. C. 12], which illustrates in a remarkable

¹ This paper is the substance of a thesis presented to the University of Glasgow for the degree of M.D., and which received commendation.

² The experiments were made while the author was resident in France.

Fig. 2.



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way the vitality and productive power of periosteum. Figure 1 is a drawing of the specimen.

The bone is broken in two places. The middle piece, *d*, lies between, and transversely to, the lower and upper ends of the upper and lower fragments. This displaced portion is completely necrosed, but new bone has been formed in considerable quantity, and so distributed as to form a sheath round the necrosed part, *E*¹, *E*², and a strong band of union between the upper and lower fragments in such a way that the function of rigidity is restored. The lower third of the shaft, *A*, is separated from the upper fragment, *B*, by the middle (necrosed) portion and its sheath of new bone, but attached to it by a column, *C*, *C*, of new bone, evidently produced from the upper end of the lower fragment where the column is almost directly continuous in its long axis, and is thicker than at its upper attachment. The junction of this new bone to the upper fragment takes place on the inner side of the latter about 2 inches from its lower extremity. The bony sheath of the dead portion is attached to the anterior surface of this column, and also to the lower end of the upper fragment. This mass of new-formed bone joins the upper and lower fragments, so that the repaired femur is perfectly rigid.

The patient had fallen from the rigging of a ship on to the deck, and, there being no surgeon on board, he was placed in his hammock without any attempt being made at fixation of the limb or treatment of the wound. When, after some weeks, the ship came into port it was found that the necrosed portion projected through a suppurating wound.

The experiments of Dr Macewen¹ have shown that "isolated fragments of bone can live even after transplantation;" and it seems fair to suppose that the fragment in this case would have lived but for the septic condition of the wound. The most interesting feature, however, is that, notwithstanding the presence of conditions so adverse to the repair of tissue, this extensive new formation has resulted. The existence of that bone prompts a query as to its origin.

Dupuytren held that the periosteum alone, through the medium of callus—distinguished as provisional and permanent

¹ Macewen, *Annals of Surgery*, 1887, vol. vi.

—was to be credited with the power of producing bone; again, Wagner asserted that from the diploë, as well as from the periosteum, callus was formed, which became ossified, and repaired the breach of continuity between two fragments of a broken bone. Paget, Virchow, Cornil, and Billroth have declared that new bone is formed from various substances, such as extravasated blood, serum, medullary tissue, &c.

In the case in point the disposition of the new bone round the detached fragment would seem to demonstrate that the vitality of the periosteum had not been destroyed, but that it had lived and enclosed the original bone with a sheath of new bone. It is scarcely possible that the periosteum could have produced the column of bone which unites the upper and lower fragments, for the new formation does not extend to the inner edge of the upper end of the lower fragment, and between the two edges can be seen absorption spaces in the old bone. From its position over the medulla and outer half of the broken surface, it is more likely that the new growth was due to the activity of the medulla, periosteum of the outer edge, and perhaps the hard bone itself.

The specimen shows grounds for the comparison of the vitality of the different parts. They were in the same wound; the detached portion of bone is necrosed, but its periosteum has lived and given rise to new bone, while the fragments which retained their vascular connections have manifested a greater amount of reproductive activity. The inference seems to be that bone deprived of its vascular supply has less vitality than periosteum under the same circumstances. Thus it would seem that periosteum is the most potent factor in bone production, since its vitality is greater than that of the medulla and hard parts.

Turning now to the records of experimental work, we have, on the authority of Macewen, that "not only do detached portions of bone deprived of their periosteum live when reimplanted in their position, but such portions are capable of living after transplantation. Parts of the deeper layers of bone without periosteal connection have been transplanted and lived and grown." It is not stated whether the transplant employed to fill up an abnormal cavity takes any active part in the cementing of itself to the pre-existing bone on which it is planted. There are experiments published to show that it does take

an active part in the repair of the breach, but the results are open to question. Nussbaum¹ relates a case of fracture of the ulna in which ligamentous union had taken place; the radius was intact. He cut down on the seat of fracture and removed the ligamentous portion; then he removed a piece of the shaft, at the fractured end, 2 inches long and to half its thickness, and inserted it between the ends of the fragments. The wound healed well, and the ulna became rigid. Now, it is not shown whether the remaining gap was filled up from the transplant or from the raw surfaces of the original fragments, though the transplant is supposed to have been the active agent.

Macewen² published a case in which he transplanted chips of tibia, got from a case where he performed osteotomy for genu valgum, in place of a humerus lost by necrosis. He cut down to where the periosteum was supposed to be and inserted the chips of bone, with the result that a considerable quantity of new bone was produced. Here, too, the question as to the exact origin of the new bone is not definitely solved, though it is assumed that the transplants were the authors. It was not suggested, though it is possible, that the periosteum survived the death of the bone, and the transplants being inserted in its vicinity may have roused its latent power of bone production. The great vitality of the periosteum is illustrated in the first case cited, and is not a rare thing to see necroses of the whole shafts of bones encased in new bone which could only arise from the periosteum.

Trueheart³ records a case in which he grafted pieces of periosteum to restore the middle third of a clavicle which had been shot away. Fresh transplants were inserted three times a month for two months, when $2\frac{1}{2}$ inches of bone had been produced. The periosteum was from a newly-killed dog. This example testifies to the remarkable vitality of periosteum, for it lived and produced bone after transplantation into an animal of a different species.

Dr Moore⁴ gave the history of a case in which he believed that an inch of new bone was produced from the medulla alone. He reduced an old dislocation of the hip, the head of the femur being on the dorsum ilii, by section of the surgical neck and continued extension. Bony union took place. Subsequently he found at the *post-mortem* examination that new bone had been formed between the shaft and the head of the bone to the extent of 1 inch. He excludes periosteal aid, because that structure could not have stretched, and therefore gives out as his opinion that the new formation was attributable to the medulla. It seems equally reasonable to argue that in simple fractures the medulla alone repairs the mischief, the only difference being that there is a greater amount of intermediary callus in the former case.

Taking advantage of the osteogenic property of periosteum,

¹ *Medical Times and Gazette*, 1875, vol. i. p. 44.

² *Lancet*, 1881, vol. i. p. 875.

³ *Medical Press and Record*, 1885, Oct. 21, p. 382.

⁴ *Lancet*, July 1, 1882, p. 108.

Schüller¹ artificially increases the growth of bone by producing a chronic inflammatory process of moderate intensity. His methods are :—"1. Production of a passive hyperæmia of the part by means of a constricting elastic band round the limb. 2. By placing the patient in such a favourable position as will best facilitate bone growth. 3. Constitutional treatment. 4. By local operations, such as the insertion of steel pins." Following on the same lines, Mickuliez² employed them successfully in cases of pseudarthrosis. He cut through the soft parts and periosteum, and inserted turpentine dressings under the latter. The dressings were renewed every three days. Ollier, with the same object, employed the method of driving in lead nails.

Seydel,³ in a case of fracture of the parietal bone, filled up the gap with chips of tibiæ, the periosteum being retained.

The above quotations show that bone still in possession of its vascular supply is capable of very extensive new formation, that this power is present to a high degree in the periosteum—perhaps on account of its greater vascularity—and to a much lower degree in the medulla and hard parts. The question as to the mode in which the transplant acts has exercised the minds of scientists ; Dr Macewen submits two propositions :—(1) That the soft parts of the transplanted bone live, and the hard parts become incorporated with the new-formed bone ; and (2) that the transplant acts only as a provisional prop, which is ultimately softened, absorbed, and got rid of by excretion.

There is another way in which the transplant may act, and this explanation is based on the results of the experiments about to be narrated, viz., that the transplant retains its original composition, takes little active part in the production of bone, and exists passively, fixed by the newly-formed osseous tissue which is mainly the product of the original bone. It is virtually a comparatively non-irritant foreign body—for no foreign body can be absolutely non-irritant—which by its bulk fills up a pre-existing cavity, which has little influence on new formative processes apart from the mechanical irritation of its presence, and which, by its bulk and rigidity, hastens recovery by necessitating a less amount of new formation.

In presenting details of the experiments it should be remarked that every case is put down irrespective of the result. The causes of failure are apparent, and may here be prefaced :—In the first place, those numbered I., II., III., VI., and VIII. were attempts

¹ *Berliner Klinische Wochenschrift*, Jan. 14, 1890.

² *Medical News*, July 6, 1890.

³ *Centralblatt für Chirurgie*, March 23, 1890.

to substitute bone, degelatinised by boiling, for the piece of bone excised. They were all unsuccessful. It was with the object of discovering whether the calcareous framework of bone would be utilised by the organism in the production of new bone either by absorption and re-deposition or by the filling of the interstices with callus and bone corpuscles. The failures may not prove that the impossible was attempted, but a comparison with the results of the transplantation of living bone shows the latter to be more practicable. While these experiments were in progress the *Medical News*¹ published the results of Hopkins' experiments, in which he found that sterilised bone, placed in contact with living bone under favourable conditions, becomes absorbed, and when placed in contact with the periosteum undergoes organisation. The other failures were due to the difficulty of administering chloroform to rabbits, and of applying suitable apparatus to insure rigidity of the limb.

Experiment I.—On March 27, 1890, a rabbit was chloroformed, the fur of its left hind leg removed, and the skin well washed with carbolic solution (1 : 20). An incision was made over the tibia, and 1 inch of its shaft removed, and replaced by a similar piece of bone which had been boiled for eight hours, and then kept for twelve hours in corrosive sublimate solution (1 : 1000) till operation time, when it was warmed in a 1 : 2000 solution. Salol dressings and lateral splints were applied.

April 1.—The animal died to-day. Since the operation it has grown much thinner. The dressing contained a small quantity of serous discharge; the skin wound was closed, and no trace of suppuration found. The foreign bone was in good position, surrounded by a sheath of fibrinous matter. On gently separating it a quantity of plastic material was found projecting from the original bone to the medulla of the foreign bone; it had a fibrous appearance, and was pink in colour. No pus was seen.

Experiment II.—On April 2 a rabbit was put under the influence of chloroform and the previous operation repeated, the only difference being that the bone had been boiled for fifteen hours.

April 9.—To-day the dressings were undone, and found to contain a little blood and serous fluid. The position was good, and primary union of the skin had taken place. No sign of suppuration.

April 14.—To-day the rabbit died. The foreign bone had so altered in position as to lie at right angles to the original bone. Suppuration had taken place; the pus was thick, and of a creamy colour, it had no smell, nor had it found exit. The skin wound had closed.

¹ *Medical News*, July 13, 1890.

Experiment III.—April 9.—To-day a rabbit was chloroformed, and after the usual preparations received, in place of $\frac{3}{4}$ of an inch of its tibia, a similar sized piece of bone, which had been boiled twenty-one hours. Dressings and splints were applied.

April 19.—Dressings were undone to-day; the wound is healed, and the bone is in good position.

April 26.—The dressings, on being removed, disclosed the end of the foreign bone projecting through the skin, which had sloughed; it was lying loose in a small quantity of pus, and was extracted without difficulty. Dressings were reapplied.

May 9.—The wound is healed, and the rabbit is well.

Experiment IV.—April 9.—To-day a second rabbit was anaesthetised, and, after the usual preparations, an incision was made over the tibia, and $\frac{3}{4}$ of an inch of the tibia removed. In its place the piece removed from the preceding rabbit was inserted, the transplant having, in the interval, lain in a warm 1:2000 solution of hyd. bichlor. The wound was sutured, and salol dressings applied.

April 19.—To-day the dressings were undone, and found to contain a quantity of serous discharge from the lower corner of the wound, where a stitch had cut through the skin. The wound appeared to be aseptic, and the transplant in good position.

April 24.—On removing the dressings to-day it was found that the skin had sloughed, owing to the altered position of the transplant, which was lying loose. It was removed and the wound dressed.

Experiment V.—The first rabbit to have been operated on to-day died under chloroform; a piece of its tibia was excised and kept warm in a solution of hyd. perchlor. (1:2000). The bone had been stripped of its periosteum.

The second rabbit received this fragment in place of the middle third of its humerus twenty minutes after excision. The usual dressings were applied.

June 7.—The dressings were undone to-day. The wound was whole, but the transplant was slightly changed in position, so that its upper end was internal to the lower extremity of the upper fragment of original bone.

June 11.—The dressings were again undone, and it was not thought necessary to renew them. The transplant was firmly fixed, and no sign of inflammatory mischief was apparent. The animal freely used the leg.

August 10.—The rabbit was killed to-day, and its humerus with the transplant were put in a decalcifying solution.

Experiment VI.—June 11.—To-day the left radius of a rabbit was laid bare, and a piece of the shaft, about 1 inch in length, was removed and put into a warm (1:2000) solution of corrosive sublimate. In its place a piece of bone, which had been boiled for twenty-one hours and warmed in the above solution, was inserted. In this case

the muscles were stitched together by deep sutures, so as the better to secure the foreign bone.

June 19.—To-day the wound was found quite healed up, the limb seemed fairly rigid, and the animal was in good condition. The cicatrix was covered with collodion and the splints reapplied.

June 23.—A slight swelling has appeared at the upper end of the incision, and on pressure a few drops of thick creamy pus exuded. The leg was washed with carbolic lotion (1 : 20) and dressings applied.

June 30.—The foreign bone came away through the hole caused by sloughing of the soft parts.

Experiment VII.—June 11.—This operation consisted in replacing the middle third of a rabbit's humerus by the piece of bone excised from the rabbit previously operated on. The bone transplanted had been about half an hour in the warm antiseptic solution.

June 19.—The dressings were removed to-day for the first time. The wound was healed, and it was not thought necessary to renew the dressings. The splints were reapplied.

June 30.—This rabbit is well; bony union has taken place, though not without a considerable amount of deformity.

September 10.—The rabbit was killed to-day, the bone and transplant were excised and put into a decalcifying solution.

Experiment VIII.—To-day a rabbit had a piece of degelatinised bone inserted in place of part of the shaft of its radius. The usual precautions were taken, and salol dressings applied.

July 8.—The dressing became loose four days ago, the bandage being gnawed through by the rabbit. The bandage was reapplied too tightly, and the limb became gangrenous.

Experiment IX.—The living bone from the previous experiment, after lying in a warm 1 : 2000 solution of hyd. bichlor. for twenty minutes, was transplanted among the deep muscles of the back of this rabbit—*sine periosteum*. The usual precautions were taken to procure asepsy.

July 8.—The skin is tense, and shows signs of sloughing. A stitch was loosened, but no pus exuded.

July 20.—The skin has sloughed, and the transplant is lying in the dressing. (In this case the transplant seems to have been too large.)

Experiment X.—August 7.—This rabbit had about an inch of its left radius replaced by a piece of similar size from the rabbit of the next experiment, both being under chloroform at the same time. Salol dressings and the usual apparatus were applied.

August 14.—Great difficulty has been experienced with this rabbit, it has undone the dressing twice by gnawing through the bandages during the night. Suppuration has ensued, and failure is the inevitable result.

Experiment XI.—This operation consisted in the exchange of about an inch of the shaft of the radius for a like piece of the previous rabbit.

August 14.—As in the previous case, this rabbit has acquired the knack of biting through its bandages, necessitating a renewal of the dressings twice since the operation. In this case, however, sepsis has not occurred.

August 20.—To-day the leg was dressed, and the transplant was found displaced, so that one end projected through the skin. An attempt at withdrawal showed how firmly it was fixed. Dressings were renewed.

September 13.—The animal was chloroformed, and an attempt made to cut off the projecting piece of transplant. The bone splintered, and spoiled the result.

Experiment XII.—October 29.—This rabbit had a portion of its humerus excised, the periosteum being left and the wound in it stitched. The animal died shortly after the operation.

Experiment XIII.—October 29.—This rabbit had a portion of its humerus excised with the periosteum, and the bone from the previous one was inserted.

October 30.—The rabbit undid the bandage, and another one was applied.

November 10.—The dressings were renewed. The wound is whole, and the position of the transplant is fairly good.

November 20.—The dressings were taken off. Bony union has taken place, the transplant being in fair position.

January 28.—The rabbit was killed to-day, and the bone put into a decalcifying solution.

The figures in Plate IV. illustrate various stages of the process.

The specimen from Experiment V. showed that the transplant had been united to the upper fragment end to end, and almost in the same plane, but to the lower fragment at an open angle. Figure 2 is a drawing of the microscopic section at the junction of the transplant and upper fragment. The transplant (*a*, *a*) for the most part retains its normal structure, but at the upper end it contains a number of absorption spaces of various sizes, the largest being at the end of the transplant. In none of the lacunæ is there evidence of new formation. The end of the original bone (*b*) is seen to be greatly excavated, and presents evidence of considerable new formation in the spaces and in the area between it and the transplant. Between C^1 and C^2 there are numerous spaces in the new bone which are connected in some places, and which are directly continuous with the original bone. This network of spaces is greater towards C^2 , and the connection with the old bone is more patent than at C^1 , where there is a layer of fibrous tissue separating the old bone from the new, on the trans-

plant side of which there is an area of granular fibrous tissue in process of ossification. The bone transplanted was stripped of its periosteum, and though it has lived there is little evidence of reproductive activity, and the new bone uniting it to the original bone seems to be almost entirely the product of the latter.

The specimen from Experiment VI. showed that the transplant in this case had changed position, so that the upper end of the transplant is not quite in the same plane as the upper fragment of original bone. Drawing 3 represents the transplant, *a*, attached to the original bone, *b*, by a mass of connective tissue, *c, c*, composed of new bone, cartilage, and fibrous tissue. The new bone is in greatest quantity near the original bone, and the fibrous tissue is most abundant round the end of the transplant, but these tissues are very irregular in disposition. The transplant contains very few absorption spaces; but the original bone is greatly excavated, and some of the lacunæ are in direct communication with the new bone. The main part of the transplant is unchanged in structure, and shows almost no reproductive activity.

Figure 4, from Experiment XIII.—This experiment has resulted in the fixation of the transplant to the original bone a little above the lower extremity of the latter, primarily by means of a false joint. The rounded end of the transplant is covered by a layer of cartilage, *a*, and fits into a socket, the sides of which are composed of new bone, *c*, also lined with cartilage. This new bone is distinctly seen to be the product of the original bone, and the fibrous tissue joining it to the transplant is granular, and contains large cells, evidently becoming ossified. The head of the transplant is greatly excavated, and the staining with logwood shows that fresh depositions of bone are taking place in the spaces. At that point where the end of the transplant, *a*, is nearest the original bone, *b*, the two are joined together by fibrous tissue containing large cells, and being of a dark granular appearance. The transplant here has undergone considerable change of structure at its upper end, and reproduction is apparent in the fresh depositions of bone in its spaces; but the original bone has been much more active, since it has produced sufficient bone to encircle the end of the transplant. The ossification of the fibrous tissue, *d*, between the transplant and the new bone forming the joint was so far advanced as to make the union rigid. No synovial membrane was discovered in the joint.

The specimen demonstrates the great productive activity of the original bone which has so enclosed the foreign bone, whose new formations have taken place mostly within itself.

The results of the microscopic examination of these three specimens bear out the statement made above, that the transplant takes little part in the production of the bone which unites it to the original bone. They show that the transplant for the most part retains its original composition, and lives.

The sections show the changes which have occurred three months after the bone was transplanted, and seem to prove that the transplants do not undergo absorption of their hard parts so as to completely alter this structure.

Besides assisting in the solution of the question as to the ultimate end of the transplant, these results may be taken as supporting the operation of transplantation of living bone in preference to insertion of decalcified bone, ivory, and other substances which become absorbed. They seem to show that the vitality of the transplant is sufficient to dispense with the method of transplanting one end of the bone, and keeping the animal in a painfully disagreeable position till union takes place before the operation is completed.

It is possible that when the transplant acquires a better vascular connection it may take a share in the production of bone, and it would be interesting to know the condition of the transplant six months or a year after the operation. There are other questions of interest, such as the liability to fracture, the repair of such a fracture, and the behaviour of the transplant when the patient becomes affected by such constitutional diseases, as sometimes cause degeneration and softening of the union of simple fractures.

THE POSITION OF THE EPIGLOTTIS IN SWALLOWING. By T. P. ANDERSON STUART, M.D., *Professor of Physiology*, and ALEXANDER M'CORMICK, M.D., *Lecturer on Surgery, University of Sydney, N.S.W., Australia.*

THE following case is of interest to physiologists as throwing light upon the functions of the epiglottis, and especially upon the position occupied by it during the act of deglutition, a subject about which there has been much difference of opinion.

A man, Dyason, aged forty-three, had epithelioma of the lower lip. This was removed by a V-shaped incision, but in eight months (Dec. 30, 1888) a secondary infection of the submaxillary lymphatic glands appeared. This was allowed to involve the skin and infiltrate the surrounding tissue. The skin ulcerated, and the lower jaw was invaded. Upon this a large part of the cheek, the lower jaw from the symphysis to the angle and the contents of the submaxillary triangle, were removed. The wound healed well.

In sixteen months (April 30, 1889), he was readmitted with a recurrence in the upper set of the deep cervical lymphatic glands. The skin, being infiltrated and ulcerated, was removed by a long incision along the anterior border of the upper part of the sternomastoid muscle, joined by two shorter incisions so as to enclose a triangle. This having been done, the large vessels were defined at the lower part of the wound, when the growth was seen to be adherent to the internal jugular vein and external carotid artery. These vessels were therefore extirpated with the growth. Further, the posterior belly of the digastric muscle lying on the growth, and all the soft structures beneath the growth right up to the mucous membrane of the pharynx, were removed. This included the hypoglossal nerve and a large portion of the constrictor muscles, as well as the greater part of the greater cornu of the hyoid bone. Although the growth extended close to the mucous membrane, the latter was apparently not invaded, so that it was left in order to avoid opening into the pharyngeal cavity. The wound healed up perfectly.

Three and a half months after this (August 15, 1889) he was again readmitted, with a recurrence between the skin and the mucous membrane of the pharynx at the site of the last operation. This time, a preliminary tracheotomy having been performed, the pharynx was plugged with a sponge, and the wall of the pharynx with the growth and skin were freely removed. The ramus of the jaw was disarticulated, so that the naso-pharynx was opened into. Part of the parotid salivary gland, the pillars of the fauces, and the tonsil

were removed. Since the growth adhered to the internal carotid artery, this vessel, with about one inch of the common carotid, was removed (the external carotid having gone in the previous operation). The skin was now sutured to the mucous membrane all round, and the marginal wound healed perfectly, so that a large opening remained as is seen in the figures. In the posterior margin of the opening are contained intact the vagus, spinal accessory, and sympathetic nerves.

In the upper margin of the hole a small recurrence appeared in the parotid; this was removed wide of the growth, and at this time the *pes anserinus* was taken away. By this time the patient had made for himself a sort of pad, kept in position by rubber bands, by wearing which he could speak and swallow comfortably, and evidently suffered but little inconvenience.

Four months after this operation (July 8, 1890) a little movable tumour, about 1 cm. in diameter, appeared about $2\frac{1}{2}$ cm. below the mastoid process at the posterior border of the sterno-mastoid muscle. This was removed by a vertical incision, and at the same time a chain of *glandulæ concatenatæ* for about 5 cm. lower down was dissected out. The spinal accessory nerve was exposed in the dissection and some of the sterno-mastoid branches divided in the line of the incision; the trunk, however, remained intact. The wound speedily healed. There was no sign of recurrence elsewhere; and this is the last operation after which the observations on the epiglottis, as hereafter referred to, were made.¹

When a glass plate—warmed to avoid the condensation of vapour—of the shape of the opening, and a little larger than it, was laid over it, one could see into the pharynx as through a window. But when we attempted to observe the act of deglutition, this method was not successful, partly because the presence and pressure of the plate interfered with the act, and partly because the air and food particles mixed with the saliva obscured the parts inside.

When, however, a suitable food was chosen, one could observe the behaviour of the epiglottis during the entire act of deglutition through the open hole without the slightest difficulty. The suitable food referred to was oysters; they were rounded, soft, and slippery, and—a matter of importance—not uninviting. The patient held the oyster on a fork until we were ready, and, on a given sign, swallowed it. Perhaps, two times out of three,

¹ I left Sydney at the end of August 1891, and the man was certainly well then; and I have a letter from Dr M'Cormick, of date Oct. 20, in which nothing is said of Dyason, so that I presume he is still well. A. S.

the bolus would escape by the hole; but the third time it would be swallowed in an apparently perfectly normal manner.

The bolus was seen to pass from the dorsum of the tongue on to the epiglottis, being received by the latter within the hollow at its tip. The bolus, therefore, after leaving the tongue, comes into contact with the inferior, posterior, or laryngeal surface of the epiglottis, and glides along thus for a certain distance. One can thus readily understand the presence of the squamous epithelium and of the taste bulbs on this surface of the epiglottis and also why the mucosa is so firmly fixed to the cartilage on this surface; indeed the lingual and laryngeal surfaces of the epiglottis may be compared to the dorsum and palm of the hand. On the former the integument is freely mobile; on the latter it is fixed. The former is merely pressed against the tongue, whilst the bolus glides over the latter. Here, therefore, to meet the friction, the mucosa is fixed to the deeper parts. During the entire act the visible part, at least, of the epiglottis remains more or less erect, firmly applied to the tongue. Never at any time was any folding backwards of it seen.

One of us (A. S.) had a meal with the patient, who had no apparent difficulty with his food, whether solid or liquid. When he had his mouthful masticated and ready for swallowing, he laid his hand upon the pad, to more securely close the opening just as he also does when he speaks, and then he swallowed quite well. His only common inconvenience is that sometimes in swallowing liquids a little remains behind, and when this is swallowed it is apt to get into "the wrong throat." This, of course, is quite easily understood, when we remember (1) the imperfectly contractile condition of the walls of the channels through which the liquid has to pass; (2) that one side of his lower jaw being absent, the elevators of the hyoid can hardly act so efficiently as normally; and (3) that the hypoglossal nerve and most of the facial nerve of one side are wanting. Occasionally a little piece of solid food gets against the pad; then it may annoy him in the same way as the liquid referred to, but this does not very often happen.

When he performs the act of deglutition without actually swallowing food, one sees the epiglottis remain vertical, and the

walls of the pharynx come forwards so as to obliterate the pharyngeal cavity.

The epiglottis stands very close to the base of the tongue; the valliculæ are not so roomy as one would have expected, even with the tongue protruded. When the tongue is forcibly pulled forwards the space is increased.

As usually described, the epiglottis helps to close the larynx, in deglutition partly because pressed down by the base of the tongue, and partly because pulled down by the aryepiglottic and thyroepiglottic muscles. Czermak says that, its cushion becoming more marked, the epiglottis is firmly pressed from before backwards upon the shut glottis. The diagrams made by Zaufal and reproduced by Hermann (*Handbuch der Physiologie*, Bd. v. pp. 416, 417) show this position. Now, this account of the epiglottis certainly commends itself, *at first sight*, as very likely to be true. That the solids and liquids swallowed should not enter the air-passages is, of course, necessary, and the folding down of the epiglottis *seems* as easy as it appears natural and likely to be efficient.

Nevertheless, doubts have been cast upon this description; and, from the evidence already published, we might say that whatever be the function of the epiglottis, it certainly does not fold down as a lid over the larynx in deglutition. This is certainly true as regards solid food; whether it may have something to do in regard to liquids, shall be seen later. The purpose of this paper, indeed, is to make use of the unique opportunity we have had for giving the *coup de grace* to the lid-like action of the epiglottis in normal deglutition. It is a case which permits us to do for the mechanical aspect of deglutition something of the sort that Dr Beaumont was able to do for digestion in the stomach from his observations upon the case of Alexis St Martin.

G. L. Walton (*Journal of Physiology*, vol. i. 1878-9) writes a paper, the object of which is to show:—"i. That the epiglottis is not essential to deglutition, even of liquids;" but "ii. That the epiglottis is an important agent in the modification of the voice." In support of these statements, Walton gives the results of his own observations and experiments, and also those of previous investigators, and gives references to pathological cases

bearing on the subject. The summary given by Walton as to the rôle of the epiglottis may be copied here. He says it has been shown—i. That the epiglottis can be removed from dogs and cats without interfering with deglutition. ii. That the cases commonly quoted to prove the connection between the epiglottis and the deglutition of fluids prove nothing; not a single case having been found, after a careful search through the reports of laryngoscopic observers, in which the lesion is shown to be limited to the epiglottis, and liquids are reported as causing a cough on deglutition. iii. There are many cases in which loss of the epiglottis has not been followed by difficulty in swallowing liquids. iv. That in failure of the glottis to close, the epiglottis, if uninjured, is able to protect the larynx; but, in the normal condition, the presence of the epiglottis is not essential to perfect deglutition. It is therefore only an additional safeguard.

The observers mentioned by Walton are Marshall, Béclard, Longet, Moura, Majendie, Giuliellini, Targioni, Larrey, Mercklin, Bonnet, Pinel, Percy, also Tuerck, Burow, Mandl, Ryland, Czermak, Mackenzie and other writers, by whom such pathological cases seemed likely to be reported; finally Norton and Revere.

In *Hermann's Handbuch*, two to three years after Walton's paper, Sigmund Mayer, the author of vol. v., part 2, 1881, refers to some of the foregoing, as also to Reichel, Louis, Schiff, and others. Schiff's writings are as far back as 1865 and 1867, and are those upon which is based the account of the function of the epiglottis, viz., that when completely extirpated by Schiff's improved method of operation, solid bodies were swallowed without any difficulty whatever, and the deglutition of liquids excited only a slight coughing that was certainly not convulsive, as it had been said to be by Longet. This slight cough, Schiff thinks, is to be explained as follows. Small portions of a swallowed liquid normally collect between the base of the tongue and the epiglottis, and thence flow downwards and outwards into the sinus pyriformis, whence they readily reflexly evoke a final act of deglutition, with the mouth and throat in the main empty, so that the whole of the liquid is now swallowed. When the epiglottis is removed, therefore, the liquid, on the one hand, is

not guided into the sinus pyriformis, so that it is not swallowed ; while, on the other hand, it is not prevented from running down into the larynx.

In the present paper we do not wish to take up the question of the influence of the epiglottis in phonation,—that shall be done later on,—but solely that of its place in deglutition. Further, one of us (A. S.), starting from this case, has made some observations leading him to a new conception as to the real mechanism of the closure of the larynx. This investigation is in progress now, and its result will be communicated in due time. These remarks are made to show why the scope of this communication has been purposely limited to a consideration of what the epiglottis does not do, rather than of what it does do.

The logically possible conditions are as follows:—

1. It always folds down ; 2. It usually folds down, but sometimes it does not ; 3. It never folds down ; 4. It usually does not fold down, but sometimes it does.

The study of our case enables us to negative 1 and 2, and in regard to 3 and 4 all that we can say is that we have never seen it fold down. Thus we are able to maintain at least 4 and we believe also 3, for, since deglutition of liquids as well as of solids was quite perfect, we cannot imagine any reason why, in normal deglutition, the epiglottis ever should fold down. Walton, however, believes that in the mechanism of deglutition the epiglottis is not absolutely valueless, since, when the glottis is from any cause not able to close, the epiglottis then acts as an additional safeguard to the larynx. In his own words—“ While the epiglottis is intact and the glottis cannot close, no difficulty follows ; ” “ when the epiglottis is wanting and at the same time the glottis cannot close, difficulty follows. ” So that “ the epiglottis *is able* to close the larynx, and it does so when the glottis fails to perform its duty. ” The evidence upon which this opinion of Walton is based is—(1) The experiment of Longet, who kept the glottis open by forceps introduced from below through the trachea, and who then saw that the epiglottis being intact, the deglutition of liquids was not interfered with. (2) Cases cited by Longet where similar results followed disease of the glottis, while the epiglottis remained intact. (3) Experiments of Walton's own, in which a dog's epiglottis was left

intact, while the aryteno-epiglottidean folds, the cartilages of Wrisberg and Santorini, and the false vocal cords were excised, the incision reaching to the ventricle on each side: the dog observed for five days showed no difficulty in swallowing solids and liquids. 4. Two similar experiments of Walton's own, in which the epiglottis too was excised; here coughing or choking followed every attempt to swallow. 5. Pathological cases with similar conditions to these last cited experiments. But, as will be shown in the communication upon the closure of the larynx by A. S., referred to above, all these cases may be explained in an entirely different way.

We must of course be quite sure that in this case we had to deal with parts, the essential connections of which had not been impaired by the operative procedures. In regard to this—

- (1) Only one side was operated on, the other remaining absolutely intact.
- (2) Even on the operated side the vagus remained intact.
- (3) No adhesions interfered with the movement of the epiglottis, the slightest pressure of the finger moving it freely in any direction.
- (4) No difference was detected in the behaviour of the two sides, the entrance to the larynx being closed symmetrically.
- (5) The patient himself states that, excepting the trifling inconveniences referred to above, he does not notice the slightest difference between acts of deglutition before and after the operations.
- (6) He speaks as perfectly as the mutilated parts permit, the only difference between his present and former speaking being that now, owing to the state of the soft palate, he has a nasal twang.
- (7) He is musically educated, and can still sing about as perfectly as before, only, of course, the nasal twang referred to modifies the sound, though, we should say, he still sings very well.
- (8) While the wound was healing, the patient was fed through a stomach tube, but when that was discontinued, he at once swallowed as well as he did

later, so that there is nothing to indicate any education of the parts, as if they had to accommodate themselves to new relations.

Thus, in conclusion, there is in this case nothing to suggest an unusual behaviour of the parts, and so we regard it as giving a true view of the epiglottis in its relation to deglutition, viz., *that it never folds down like a lid to cover the entrance to the larynx.*

BIFURCATION OF THE FEMORAL ARTERY WITH
SUBSEQUENT RE-UNION. BY JAMES MUSGROVE,
M.D., M.R.C.S., *Demonstrator of Anatomy in Edin-
burgh University.*

SINCE the historic case in which Sir Charles Bell failed to arrest at once pulsation in a popliteal aneurism by ligaturing the supposed femoral artery, considerable importance has been attached to varieties of this vessel, especially to that form in which there is division of the femoral into two stems, uniting again to form a single trunk before piercing the adductor magnus muscle. In the case referred to, Sir Charles Bell¹ cut down on the femoral artery and ligatured the exposed vessel for the cure of popliteal aneurism. It was observed by his assistants that there was pulsation by the side of the ligature, and that the beating of the aneurism had not been arrested. The surgeon remarked, "Well, be it what it may, I shall do no more; we have done all we ought to do." A few days after the operation the patient died of erisypelatous inflammation, and it was found on dissection that the femoral artery, after giving off the profunda branch, divided into two vessels, of which only one had been tied, and that the "pulsation near the ligature" had been caused by the parallel stem. The two vessels re-united to form a single trunk, passing on as a normal popliteal artery.

A variety similar to this has recently occurred in the dissecting-room at Edinburgh University. The subject was a muscular adult male, and the anomaly was present on the left side. The femoral artery, a continuation of a normal external iliac, appeared from behind Poupart's ligament (see figure) in the usual position as a single trunk, 1 cm. in diameter, and took the normal course through Scarpa's triangle and Hunter's canal in a line towards the prominent part of the internal condyle. In the upper part of the vessel there was nothing unusual, but, 9 cm. below Poupart's ligament, after giving off the profunda femoris, the main artery divided into two stems, inner and

¹ *London Med. and Phys. Jour.*, vol. lvi. p. 134.

outer, which passed down side by side for a distance of 13 cm. and then reunited to form a single vessel, which passed through the adductor magnus muscle into the popliteal space. The two

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stems were in the same plane, except at the lower end, where they were slightly twisted, so that the outer came a little in front of the inner, though still retaining its position to the outer side. On comparing the two vessels, the outer branch

seemed, if anything, a more direct continuation of the parent stem, but was smaller than the inner, measuring in diameter $\frac{1}{4}$ mm., while the inner was 6 mm., the size being gauged with calipers when the vessels were cleaned. The outer part also differed from the inner in that its diameter was not quite so uniform.

As far as the bifurcation, the femoral artery lay on the psoas and pectineus muscles. Below that point the parallel stems of the divided vessel were covered by the sartorius throughout the greater part, if not the whole, of their extent. On its outer side the external branch was in contact with the vastus internus, while behind the two vessels the adductor longus was placed, separated from them, however, by an undivided femoral vein. At the upper part of Scarpa's triangle the vein occupied its normal position on the inner side of the artery, and then passed outwards, so as to lie behind the femoral, where the artery divided in this unusual manner. Still passing outwards in its course behind the divisions of the femoral artery, the vein lay on the outer side of the two trunks (and slightly behind them) before their reunion. Beyond the presence of an unusually large cutaneous branch of the obturator nerve, appearing beneath the lower border of the adductor longus, and passing down the inner side of the knee and leg, there was nothing unusual in the nerves of the thigh. And this obturator branch was separated by some distance from the femoral artery. The long saphenous nerve passed downwards in front of the divided femoral vessel, and at the lower part of Hunter's canal appeared on the tendon of the adductor magnus, in its normal position, accompanied by the anastomotic artery. On the outer side of the external branch of the femoral lay the nerve to the vastus internus. No structure was found passing between the two divisions of the artery, but as the vessels had been partly dissected, it was not possible to determine the relation of the sheath to them—whether they were invested by a common sheath with a dividing septum, or each vessel enclosed in a separate covering. Nothing unusual was noticed in the arteries of the buttock or popliteal space, and the deep epigastric and deep circumflex iliac vessels arose in the normal manner from the external iliac.

In describing the branches it will be convenient to arrange them in three groups—first, those given off from the femoral before division; secondly, those from the stems, inner and outer, resulting from the bifurcation; and, lastly, the branches of the re-formed trunk before it pierced the adductor magnus to become the popliteal.

From the femoral before division a branch was given forwards from its anterior aspect 1·2 cm. below Poupart's ligament. This branch divided into superficial circumflex iliac, superficial epigastric, and superficial pudic arteries. Further down, 2½ cm. from Poupart's ligament, there passed backwards between the psoas and pectineus muscles a large internal circumflex artery. The profunda came from the outer and slightly from the posterior aspect of the femoral, 4 cm. below Poupart's ligament, and, after passing outwards and downwards, turned behind the femoral vessels in the usual manner. In its course the profunda gave outwards a branch dividing into two parts, one going upwards and outwards under the rectus femoris, and another downwards and outwards also under the same muscle. Another vessel arose from the front of the profunda, and was distributed with the nerves to the vastus externus and crureus. Passing behind the adductor longus, the profunda sent backwards perforating arteries and branches to the adductor muscles and hamstrings. After giving off the profunda and the other-mentioned branches, the femoral artery bifurcated 9 cm. below Poupart's ligament. From the inner vessel resulting from this division, three small branches were given off to the adductors longus and magnus, at 5·5, 6·5, and 9·5 cm. respectively from the bifurcation. From the outer vessel a greater number of branches were given. Two small twigs from the upper part passed outwards, but their distribution was not ascertained. For the supply of the vastus internus four branches were given off from the outer trunk,—one at 3 cm. below the bifurcation, another 2·5 cm. below this, a third a short distance above the reunion, and a fourth where the two vessels joined again. The sartorius received a small twig from the outer stem 8·5 cm. below the bifurcation. From the trunk formed by the reunion of the vessels, a large branch passed to the lower part of the sartorius. A branch from the posterior aspect of the trunk went backwards through the

adductor magnus to end in the popliteal space. And lastly, the anastomotic artery arose from the trunk 5 cm. below the fusion of the vessels, immediately before the femoral disappeared through the adductor magnus.

From the above description it will be evident that there is nothing in the relations of the femoral artery to account for this unusual variety. Nor is there anything in the arteries of the adjoining regions, or in the branches of the femoral itself, to explain why there should be present, in front of the adductor longus, two parallel vessels instead of a single femoral artery.

In consulting the literature on this subject, I have been able to find records of eight authenticated cases of this variety, with a reference in Henle's *Handbuch der Anatomie* to an imperfectly recorded case by Ducachet. In the following table Ducachet's case has been included, but I have purposely omitted the instances mentioned by Sandifort, Portal, and Gooch, as there is no evidence that they were examples of this variety,¹ and I have not given the case found by Mears, as it is only mentioned by Kelly² without a complete dissection having been made. Bell's case has already been referred to. Houston, in writing his account, pointed out the difficulty which such a femoral artery might present to the surgeon, not knowing at the time that Sir Charles Bell had actually operated on such a case in the previous year. In the third case, dissected by Tyrrell, the abnormality was found in a foetus. Quain met with only the one case in 1200 bodies, and this double femoral must be looked upon as one of the rarest varieties of the vessel. The specimen which I have described has been placed by Sir William Turner in the collection in the Anatomical Museum in Edinburgh University. It is the first and only case which has occurred in the University dissecting-rooms during his experience of thirty-seven years.

¹ See Quain, *Comment. on the Arteries*, pp. 514, 515.

² *Amer. Jour. Med. Sc.*, Jan. 1882.

TABLE.

	Recorded by	Publication.	Date.	Side of body.	Sex.
1	Sir Charles Bell.	<i>Lond. Med. and Phys. Jour.</i> , vol. lvi. p. 134.	1826	Left	Male.
2	Houston.	<i>Dublin Hosp. Report</i> , vol. iv. p. 313.	1827	Left	Female
3	Tyrrell.	<i>Quain's Comment. on the Arteries</i> , p. 515.	1844		
4	Quain.	Do. do. p. 515.	1844	Right	Male
5	Tiedemann.	<i>Tab. Art. Corp. Hum.</i> , Taf. li. fig. 1. ¹	1846	Left	Male
? 6	Ducachet.	<i>American Med. Times</i> , March 1863. Cited by Henle as imperfectly recorded (<i>Handbuch der Systematischen Anat.</i> , 1868, Band iii. p. 300).	1863		
7	Griffith.	<i>Amer. Jour. Med. Sc.</i> , Jan. 1882.	1882	Right	Male
8	Howard Kelly.	Do. do.	1882	Right	Female
9	Bianchi.	<i>Sperimentale</i> , tomo lxiii. pp. 383-387.	1889	Right	Female
10	Musgrove.	<i>Jour. of Anat. and Phys.</i> , vol. xxvi. p. 239.	1892	Left	Male

Since writing the above account I have received, through the courtesy of Dr Edgar Willett, notes of a specimen in St Bartholomew's Hospital Museum, numbered 3574, the description of which reads thus:—"A femoral artery from which a large branch, arising in the upper part of the thigh, is continued parallel with the trunk, and, after a course of seven inches, ends in the popliteal artery." This is probably the specimen which Tiedemann² mentions as having been seen by himself.

¹ The description of this figure in the explanation given by Tiedemann appears, evidently through an error, under fig. 2 instead of fig. 1.

² *Tab. Art. Corp. Hum.* The explanation of pl. li. fig. 1 (2).

Fig.

Fig. 3.

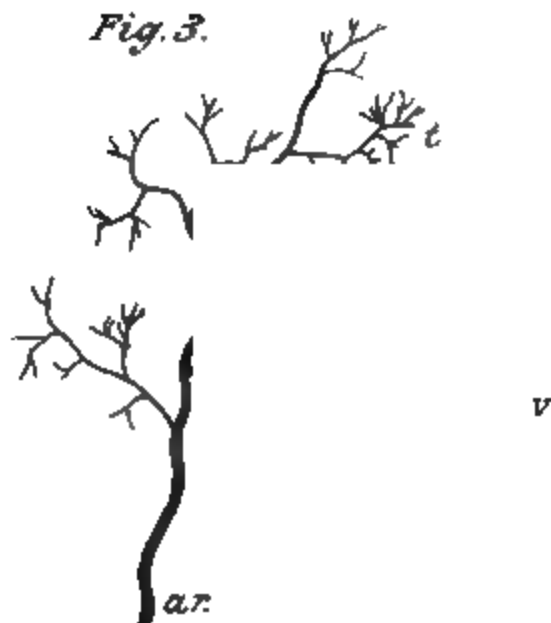


Fig 2.

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THE BLOOD-VESSELS OF THE RETINA, WITH A
METHOD OF PREPARATION FOR LANTERN DE-
MONSTRATION. By JAMES MUSGROVE, M.D., M.R.C.S.,
Demonstrator of Anatomy, Edinburgh University.
(PLATE V.)

Read before the Scottish Microscopical Society, December 1891.

WHEN we consider the important part which the retina plays in the sense of vision, and that the rays of light impinging on the rods and cones have first to traverse the plane in which the vessels lie, it must be admitted that too little attention is paid to the vascular arrangements of this membrane. In carrying out an investigation on this subject, various methods may be adopted. The vessels may be rendered apparent by merely staining their walls; or the vessels may be examined with the aid of the ophthalmoscope either during life or immediately after death. Or again, a third method may be adopted—examining detached portions of the retina after artificial injection. I have endeavoured to combine the advantages of the last two methods by preparing the whole injected retina as a lantern slide.

As I believe the method of investigating and demonstrating the blood-vessels of the retina with the aid of the oxy-hydrogen lantern has not previously been shown, it is necessary that I should describe in detail the manner in which the slides are prepared. The following observations have been made on the retina of the ox, though the mode of preparation would seem, from a few experiments that I have made, to be equally applicable to the retina of the sheep, rat, and human subject, provided that the eyes can be obtained within a short time after death.

Mode of Preparation.—In the case of the ox, the injection can be made quite well after the eye has been removed from the orbit. In taking out the eye, as much as possible of the fat and muscles of the orbit should be removed as well, and the vessels cut far back. The injection is made through the ophthalmic artery with an ordinary hand-syringe. Very good results are obtained

with melted carmine-gelatine, but it is important to keep the eye in hot water for half an hour before the injection is made, and after the nozzle has been inserted, in order that the gelatine may flow readily through the smallest vessels. It is better to arrest the "bleeding" points, especially the veins, while the injection is being made. In order to obtain a full injection of the vessels, considerable pressure has to be used. I have generally found that it required as much pressure as could be exerted with one hand in order to fill the vessels completely. The tension of the eye-ball and the state of the conjunctival vessels serve as a guide to the progress of the injection; but sometimes it will be found advantageous, especially when the pupil is large, to place the eye under clear water, and throw a bright light on the retina, and thus examine the actual state of the vessels before withdrawing the nozzle of the syringe. Although there is usually extravasation between the choroid and sclerotic, I have only on one occasion burst the retinal vessels, and in that instance the eye was not obtained until some days after death. In all other cases the eye has been injected soon after death, sometimes while still warm. Although carmine-gelatine gives very good results, it does not afford a complete view of the vessels, because the colouring matter in the capillaries is too small to produce any effect on the screen. To overcome this difficulty I tried an injection-mass composed of gelatine and a preparation of logwood, which gave excellent results. Unfortunately, I have not been able to make it a second time, but hope to obtain it again, and publish the formula in some future paper on this subject. When the injection is complete, the eye must be cooled for a few hours, in order to allow the gelatine to set. The next stage consists in the removal of the entire retina without tearing the membrane. This can best be done from the front. The cornea is removed by making a cut with scissors along its margin. Then the iris is removed in the same way, taking care to wash off with water any pigment from the iris which remains, since it is difficult to remove it from the retina if once it touches that membrane. The lens is next removed by cutting through the anterior part of the capsule, after which the vitreous, along with the capsule of the lens, may be withdrawn from the eye by pulling on it with forceps, at the same

time making pressure on the posterior part of the sclerotic with the other hand. After the removal of the vitreous, the retina will be found hanging down from the optic disc, and its attachment there is to be divided with a knife, sufficient room being gained for the purpose by cutting away part of the sclerotic. If great care be taken that no part of the retina is torn away in the removal of the vitreous, the entire retina may be freed and floated out in water. Perhaps the most tedious part of the process consists in spreading out on glass the retina thus detached. This must be done with the aid of a soft camel-hair pencil only, and it is important that no hardening agent such as alcohol be used, since this has a tendency to cause unequal contraction of the gelatine. For the retina of the ox, thin lantern slides of ordinary size will be found most suitable. By carefully stretching the peripheral parts, and slightly crowding together the central portions, it will be found possible to adapt the whole retina to the flat surface of the glass. The dehydration of the specimen thus prepared is carried out by slowly drying for twelve hours in a warm oven, at a temperature below the melting-point of the gelatine. Should any air-bubbles have got between the retina and the glass, they must be removed by pressure with the camel-hair pencil before the specimen is dried. After dehydration the retina is clarified by allowing it to remain for two or three days under oil of cloves, until all opacity is removed. At the end of this time the clove oil is drained off, and the retina covered with solution of balsam in benzol, and another thin lantern slide used as a cover-glass. Should it be desired to take a direct negative photograph of the vessels, this can easily be done, before the clove oil is removed, by placing the silver paper directly in contact with the specimen and exposing it to light. The clove oil, which will have sunk into the paper, can be removed with methylated spirit, and the development proceeded with.

Specimens prepared in the above manner are equally suitable for naked-eye and lantern purposes, and for microscopic examination if sufficiently thin glasses have been used. There is absolutely no diffusion of the colouring matter into the tissues surrounding the vessels, whereas, in making the injection with

gelatine and aniline dyes, I have found the diffusion so great as to render the specimens worthless.

To the naked eye, specimens prepared by this method convey a very good impression of the general distribution of the retinal vessels. Both arteries and veins are fully injected, and there is a red tint given to the whole membrane when carmine-gelatine is used which would suggest that diffusion had taken place, but which is seen, on microscopic examination, to be due to a dense capillary plexus pervading the whole extent of the retina from the optic disc to the ora serrata. The arteries are distinguished from their companion veins by the fact that their diameter is almost invariably less than that of the veins, though the following description of the vessels was verified by a specimen in which I was fortunate enough to obtain the arteries injected black and the veins brown.

As the central artery appears at the optic disc, it gives to the lower part of the retina from two to four branches (fig. 1, Pl. V.). Of these branches two pass more or less horizontally, one going towards the nasal and the other towards the temporal side. From these two vessels branches pass right and left until the main stem is exhausted. Those passing upwards from these two vessels pour their blood into a region which may be spoken of as the intermediate zone, where only capillaries are found. In addition to the inferior branches mentioned, there are generally two others passing downwards. These go to the lowest part of the retina. Occasionally they pass for a short distance as one trunk, which divides into two branches, to be distributed, one to the nasal and the other to the temporal side at the most inferior part of the retina. The veins accompanying these last two vessels are much larger than the arteries, draining the blood from a much more extensive field than is supplied by the arteries. After giving off these four branches, the main artery courses in an almost straight line upwards and outwards. Sometimes, however, it may be seen to be entwined around the corresponding vein once or twice. The main stem gives off two or three branches to the temporal side, and an equal number to the nasal portion of the retina, and sometimes terminates by dichotomous division. The first two branches given off (one on the temporal side, the other on the nasal) send

twigs downwards to the intermediate zone already referred to. In nearly all cases the branches of the artery given to the inner or nasal side are larger than those to the outer side, since the inner part of the retina is larger in consequence of the point at which the optic nerve pierces the sclerotic in the ox. Dichotomous division, although not common in the parent stems, frequently occurs in the smaller branches, and is almost universal in the terminal twigs. The veins in the upper part of the retina have a general correspondence to the arteries in position and extent, though a distinction has to be made between the main stems and the smaller branches in respect to position. In the case of the larger vessels, the artery and vein lie side by side, but, in the smaller branches, the veins and arteries alternate and are separated from one another by a region where the capillaries are found. In the retina of the rat this alternation is found in the main stems themselves.¹ Although there is this correspondence between the arteries and veins in the upper part of the retina, there is a marked difference at the lower part. The veins here accompanying the two lowest arterial branches are much larger than the corresponding arteries, and form marginal vessels, of which the temporal is much larger and more constant than the inner. Indeed, the inner, as a marginal vessel—that is to say, a vessel near the ora serrata—may be absent. These veins form what has been referred to by Leber² as the *circulus venosus retinæ anterior*; though it must be pointed out that the two veins together do not form more than half a circle and are not directly continuous with one another. In examining a series of retinæ there is found to be a remarkable uniformity in the distribution of the branches of both arteries and veins. The varieties are not more numerous than might be met with in the vessels of the limbs; but there is a great difference in the arrangement of the main stems in the retinæ of different animals. Thus in the rat, according to Hesse,³ the central artery, on appearing at the optic disc, breaks up into six equal stems, which pass in a radial manner towards the ora serrata. Alternating with these are six converging veins. In the human

¹ Hesse, *Archiv. für Anat. u. Physiol.*, 1880, p. 219, and pl. vi. fig. 1.

² *Handbuch der Augenheilkunde*, 1876, band ii. p. 311.

³ *Opus cit.*, p. 219.

subject a single artery, accompanied by a corresponding vein, "soon divides into branches, usually two—one above, the other below—each of these again dividing into two branches which arch out towards the sides" (Quain).¹

When the specimens are shown on the screen with the aid of the oxy-hydrogen light the distribution of the vessels can be still more clearly seen, and there is brought out very prominently the fact that, as regards the distribution of vessels, the retina may be divided into three parts—a lower portion containing branches of the four arteries and veins already described, an upper part containing also large vessels, and an intermediate zone entirely free from large vessels except in so far as it is traversed by the main stems of the artery and vein in their course to the upper part of the retina. This intermediate zone appears on the screen as a wide belt (fig. 1, Plate), not unlike a "watershed" in appearance, but when examined under the microscope, the part occupied by capillaries only is much narrower than it appears on the screen. In the human retina there would appear to be a region corresponding to this intermediate zone, as may be seen in Liebreich's *Atlas of Ophthalmoscopy* (Pl. I.). The same region is indicated by Schwalbe.²

If the injection be made under very high pressure, the retina has a blotchy appearance as though the injection material had been extravasated into the tissue of the retina. But on the screen, or still better under the microscope, these blotches are seen to correspond to the distribution of the terminal branches of the arteries (fig. 3, Pl. V.).

It might be thought that the lantern method of demonstrating the retina would afford an excellent opportunity of comparing the vascularity of the different parts of the retina by giving a view of the whole membrane at once, and would readily allow a comparison to be made of the retinæ of different animals. There can be no doubt about its usefulness in respect to the former, although here allowance has to be made for the fact that, unless the maximum pressure is used, the retina around the optic disc will appear more vascular than the parts near the ora serrata. More than one specimen in my possession illustrates

¹ *Elements of Anatomy*, ninth edition, vol. ii. p. 421.

² *Lehrbuch der Anatomie der Sinnesorgane*, 1887, fig. 58, p. 120.

this point, but only where the maximum pressure had not been used. As regards the comparison of the retinæ of different animals, I agree with Dr J. W. Barrett¹ in appreciating the immense difficulty in making accurate quantitative comparisons. After seeing a dozen slides of the retinæ of the ox thrown on the screen, one might be led to conclude that there was a great difference in the vascularity of the retinæ of the ox alone, and indeed in the two eyes of the same animal, were it not known that different pressures had been used. With a very low pressure there are injected only the main stems of the arteries and veins, together with only a number of the capillaries. This might suggest that there was a direct connection between the arteries and veins, but no such anomalous connection exists, although it can be seen that there is a connection between the arteries and veins by means of some capillaries which are not complicated in their course, while in most parts of the retina the capillaries form a dense plexus, which must afford considerable resistance to the passage of blood from the arteries to the veins. With a still greater pressure, all the branches of the arteries and veins are injected, and the capillaries filled but not distended. When the maximum pressure is used, and the outgoing veins of the eye clamped, the capillaries are not only filled, but also distended, although they do not rupture, any undue pressure being relieved by extravasation taking place into the perichoroidal lymph space.

Microscopic examination of the specimens reveals several points which are not to be made out on the screen. The small arteries present a more tortuous course than the veins, and show a tree-like arrangement of the branches (fig. 3, Pl. V.). The tufts (*t* in fig.) are seen to be the cause of the blotchy appearance of the specimen when seen with the naked eye. There is also seen, throughout the whole extent of the retina, to the very margin of the membrane, a dense capillary plexus (fig. 2). The capillaries immediately associated with the arteries differ from those directly connected with the veins in that they form irregularly shaped meshes, with the appearance of a confused network, whereas those pouring their blood directly into the veins have more regularly rhomboidal meshes, and show a general convergence towards the vein in which they terminate. As mentioned

¹ *Journ. of Physiol.*, vol. vii. p. 238.

before, the smaller arteries are separated from their companion veins by an interval, which is occupied by this capillary plexus. When the part of the retina, which we have referred to as the intermediate zone, is examined under the microscope, it is found that the region free from vessels larger than capillaries is much less than it appeared on the screen; for it is reduced to a thin wavy band, the wavy character being due to the encroachment upon it by branches of the vessels from the upper and lower zones alternately.

A word or two must be said in regard to the question of anastomosis of the retinal vessels. This method of investigation allows me to state definitely that there is no anastomosis between the branches of the artery, except through the capillary plexus, and that the veins do not directly communicate with one another. I am satisfied that no anastomosis takes place between the vessels of the retina and those of any other part of the eye, unless it be, as stated by several writers on the subject, with the choroidal vessels in the neighbourhood of the optic disc. On this point these specimens yield no information one way or the other.

In addition to the specimens described, I made preparations of the injected retina for vertical sections (fig. 4, Pl. V.), and found that the vessels lay chiefly in the nerve-cell layer, the inner molecular layer, and the inner nuclear layer. Only rarely were capillaries found beyond the inner nuclear layer, and they never extended as far as the outer nuclear layer, so that the outer layers of the retina are entirely free from vessels. And this is in harmony with the statements previously made by Hesse and His¹ in reference to their observations on the retina of man, dog, and the rat, and coincides with the statements of other observers. In the specimens which I have hitherto examined, the nerve-fibre layer has appeared almost free from vessels. This, I am aware, is contrary to what has been found by the observers referred to; and a more extended examination of the retina in vertical section may show that this peculiarity is confined to certain parts of the membrane.

It was pointed out by Hesse and His that there are two

¹ *Archiv. für Anat. u. Physiol.*, 1880, pp. 219-231.

plexuses of capillaries, one in the nerve-cell layer and another in the inner nuclear layer. In the ox there would appear to be a third region where the capillaries tend to assume a horizontal position—in the middle of the inner molecular layer. Since both arteries and veins were injected with the same material, I have not been able to confirm the statement made, that the plexus in the nerve-cell layer is especially connected with the arteries, and the deeper one with the veins.

From the foregoing account it is apparent that the retina, far from being a membrane with a few vessels only, as might be inferred from ophthalmoscopic examination, is permeated throughout its whole extent by a dense capillary plexus.

EXPLANATION OF PLATE V.

Fig. 1. Natural size drawing of whole retina of ox when prepared as a lantern slide. The arteries are deep black and the veins half tint.

Fig. 2. Camera lucida drawing of capillary plexus $\times 50$. A vein and an artery are also seen.

Fig. 3. Shows tree-like arrangement of terminal branches of artery. v = vein. ar = artery. t = tuft $\times 10$.

Fig. 4. Vertical section of retina.

ON—Outer nuclear layer.

OM—Outer molecular layer.

IN—Inner nuclear layer.

IM—Inner molecular layer.

NC—Layer of nerve-cells.

NF—Layer of nerve-fibres.

ON A POSSIBLE OBSOLETE FUNCTION OF THE AXILLARY AND PUBIC HAIR TUFTS IN MAN.

By LOUIS ROBINSON, M.D.

THE extraordinary power of the grasping muscles in the hands and arms of newly-born infants revealed by the experiments recorded in my articles on "Darwinism in the Nursery" (*Nineteenth Century*, Nov. 1891), and "Infantile Atavism" (*Brit. Med. Journal*, Dec. 5, 1891), which seemed to be a projected vestige of the chief means of self-preservation among the young of the arboreal quadrumana, led me to consider whether there might not be found in the human adult some vestigial trace of a point of attachment of the offspring to the parent.

Attributes which have been essential for the preservation of the species from extinction for prolonged periods are exceedingly persistent, even when by a changed environment their purpose has become obsolete.

In this case the efficiency of the prehensile power of the young as a means of self-preservation depended on a suitable holding-place in the parent, and both parent and offspring of course shared equally (if we may so speak) in the responsibility of preserving the race. It therefore struck me that if no such remnant of this means of rendering easy the maintenance of the hold of the young were present, it would weaken my contention that the power of grip in the babe is akin to, if not a direct succession of, the means adopted by the infant ape to cling to its mother when in time of peril she cannot spare an arm to secure it from falling. If, on the other hand, such remnant of a gripping-place were shown to exist, the whole argument would receive a very notable measure of support.

Wallace and other naturalists have observed that young apes hang beneath the body of the mother, and sustain themselves by grasping the hair; and it struck me that possibly the axillary and pubic hair tufts, so noticeable in man, might be the very vestigial remains I sought for; especially as the functions allotted to these appendages by physiologists had never satisfied me when I came to consider their universal appearance in all

faces which are hairy at all, and I put this suggestion forward in the article on "Infantile Atavism" mentioned above.

On further consideration, the following reasons appeared to give some measure of sanction to the suggestion:—

(1) The hair in these parts appears *at puberty*, when the whole organism is being modified and adapted for the production and maintenance of offspring.

(2) It appears in both sexes (unlike the hair on the face in the male, which, by the way, does not commence growing at puberty, but later, *i.e.*, at the period when the skeleton and muscles are developed in such a degree as to enable the man to meet his rivals or enemies in *fight*), and is often earlier and more fully existent in the female than in the male.

(3) It exists in parts where the young of tree-climbing beings could attach their hands without danger of violent contact during the rapid progress of the parent among the branches. In the one case the arms and shoulders of the parent would protect the grasp of the hands of the young from being thus loosened, and in the other the angle between the abdomen and thighs would shield the "feet" in a like manner.

(4) I have ascertained by measurement that in most cases the situation of the axillary and pubic tufts is within easy reach of the hands and feet of infants when their limbs are extended, if the body of the adult is in the position taken by that of an anthropoid ape when climbing. The front of the chest and pelvis are thereby approximated, and we may reasonably suppose that in the case of our arboreal ancestors the arms of the young were not shorter than those of the modern infant.

I have noticed also that an infant retains its hold best when the hands are wide apart.

(5) It does not seem probable that in either situation, especially in the case of the axillary tufts, the hair could have been retained for purposes of display, as it doubtless is on the face in the male.

(6) As an objection to the view that the pubic hair is an adjunct to the copulative apparatus (though it could scarcely be argued that it is necessary), is it not a fact that among man's nearest congeners in the animal world the reproductive act is performed after the fashion of quadrupeds, and that the

alteration of habit in that respect in the human species is comparatively of recent date?

(7) When it is suggested that the office of the axillary hair is to mitigate friction, or direct or absorb the sweat during exertion, we must remember that children, who are more active than adults, get on very well without it, and practically never chafe at this spot; also that in active animals, such as dogs, horses, &c., it has no analogue.

(8) It would seem as if this hair, unless it served some *essential* purpose in the past, might have proved in the main detrimental, by becoming a harbouring-place for disease germs and vermin—as, for instance, the *pediculus pubes*; and if detrimental and not necessary, would it not have been in the course of time eliminated?

(9) The hair in these regions is obviously not needed as a protection from cold.

I was so much struck by the cumulative force of these considerations that I ventured to submit the chief points of what appeared at first a very bold theory to several leading comparative physiologists, including Professor Flower and Professor Romanes, and was much gratified to find that they deemed the matter worthy of further careful investigation. Professor Romanes especially, whom I have to thank for the full and kind manner in which he criticised the suggestions put forward, appears to think that it is possible that I have cleared up a very obscure problem with regard to the past uses of certain vestigial hair tracts.

Several objections were raised by my correspondents, and with the chief of these I will deal very briefly.

(a) It was suggested that in the case of no known anthropoid ape does the male assist in carrying the young; and this, if a fact, would be most pertinent, because the hair is much more fully developed in the male of our own species than are other vestigial offspring-maintaining organs, such as the mammary gland and nipple, &c.

I find, however, that Hartmann¹ quotes Diard to the effect that certain male gibbons assist in carrying the helpless young; and it is an apposite consideration that in these apes the period of immaturity is prolonged almost as much as in man.

¹ *Anthropoid Apes*, p. 253.

(b) That the reason above suggested for the persistence of the pubic hair, will not account for the hair on the labia or scrotum, perineum, or around the anus.

This appears to me rather a weighty objection, but at the same time I would suggest, by way of answer to it, that the intimate relationship of the trophic nerves of these regions might account for the fact by bringing about a similar condition of nutrition and growth-function in the several parts so associated.

(c) The sensitiveness to pain exhibited by the nerves of the axilla and pubes when the hair is pulled seems to render it improbable that it was ever meant to support the weight of the young.

It is obvious, however, that if the weight were distributed (altogether possibly not exceeding three or four pounds in arboreal beings—for young apes do not accumulate fat like modern infants), each tuft would have no large share to sustain; and it is easily demonstrable that the hair and other dermal structures change rapidly in their degree of sensitiveness with changing conditions. All tend to become hyperæsthetic by disuse or unaccustomed protection from contact, and all show remarkable insensibility to pain when habitually exposed to friction or other violence.

A case in point is the lock of hair in the mane of a horse commonly grasped by the rider in mounting. I have noticed that young horses, when first broken in, flinch when this is pulled, but afterwards become quite indifferent.

No doubt other objections will be raised, and I do not wish to appear too eager to attach much faith to all points of a theory which is, I believe, an entirely novel one, and which has not yet been given the advantage of the very salutary process of running the gauntlet of hostile criticism. Still, I think that, as a provisional working hypothesis, it is well worthy a place, and after much consideration it does not appear to me likely that it will be ousted by any other view now current, when each is tested by being set to account for all the most noteworthy facts.

NOTES ON SOME OF THE VISCERA OF RISSO'S
DOLPHIN (*GRAMPUS GRISEUS*). By Professor
Sir WILLIAM TURNER, F.R.S.

IN September 1889 I heard from my friend and former pupil, Mr Charles Anderson, M.B., of Hillswick, Northmavine, Shetland, that a small school of dolphins had been captured at that place, and that from their appearance he believed them to be Risso's dolphin. Through his most obliging help I was able to secure four skulls, two skeletons, and the thoracico-abdominal viscera of two of these animals. The dolphins ranged in length from 8 feet 7 inches to 10 feet 5 inches.

Although four specimens of this rare dolphin have been recorded¹ as captured in the English Channel, and a fifth specimen as probably caught there,² no example, so far as I know, had been described as seen in Scottish waters, until I recorded in December 1891 the capture of these animals in Shetland.³ This dolphin may now, therefore, be added to the Scottish fauna, and Hillswick Bay is the most northerly point at which it has yet been seen.

It is unnecessary that I should give a full account of the anatomy of Risso's dolphin, for Professor Flower has already described at length and figured the skeleton. Supplementary observations on some of the bones have also been given by MM. van Beneden and Gervais,⁴ M. Fischer,⁵ and Mr Balkwill. M. Fischer has made some observations on the viscera, and a more complete description of many of the internal organs has been given by Dr Murie. I have, however, noticed some arrangements in the course of my dissection which have not been sufficiently explained by previous writers, and amongst

¹ Rev. C. A. Bury, *Zoologist*, 1845; Prof. Flower, C.B., *Trans. Zool. Soc.*, 1871; H. Lee, *Proc. Zool. Soc.*, 1877; F. H. Balkwill, *Trans. Plymouth Institute*, 1886-87.

² Prof. Flower, *op. cit.*, and Dr James Murie, *Jour. of Anat. and Phys.*, Nov. 1870, vol. v.

³ *Proc. Roy. Physical Soc.*, Edinburgh, Dec. 1891.

⁴ *Ostéographie des Cétacés*.

⁵ *Annales des Sciences Naturelles*, viii., "Zoologie," 1867.

these I may especially refer to the male organs of generation, for the specimens examined by M. Fischer and Dr Murie were both females.

Organs of Respiration.—Dr Murie gives a very careful description of the spiracular cavity, its sacs and the larynx, so that I need not make further reference to these parts. All that he says about the lungs is that they comport themselves to those of the Pilot Whale. When the lungs were artificially inflated I noticed some points in their anatomy which have not been recorded by Murie in his description of *Globiocephalus melas*,¹ and to these I shall now refer.

Each lung might be regarded as possessing a sterno-costal and a vertebro-costal portion, the plane of demarcation between which was a deep indentation on the convex costal surface, which passed obliquely from the anterior and dorsal part of the lung ventrally and backwards to the diaphragmatic border. The sterno-costal portion, which was in relation to the pericardium, was characterised by its thinned and attenuated appearance. In some places it was so thin that in the collapsed state of the lung it was difficult to recognise it as consisting of lung-substance; but when artificially inflated from the windpipe the air freely entered it and dilated the air lobules. In a few places near the sternal border the air lobules were absent; the layers of pulmonic pleura on opposite aspects of the lung were in contact with each other, and in these places the lung was semitranslucent. The sternal border of the lung was indented and sinuous in outline. The apex of the lung was also indented and divided into lobelets, which varied in length from 1 to 2 or 3 inches; four were present at the left apex and three at the right, but those on the right were somewhat the larger. The costo-vertebral part of the lung was thick and adapted to the costo-vertebral hollow. The diaphragmatic border was attenuated, and the diaphragmatic surface was deeply concave. When the lungs were collapsed the pleural surface seemed as if tough and opaque, which is the character so often described in connection with the cetacean lung.

Abdominal Viscera.—The *Stomach* has been described both by M. P. Fischer and Dr James Murie, and has been shown

¹ *Trans. Zool. Soc.*, vol. viii. part iv., 1873.

by these naturalists to resemble in its form, in the number and in the general arrangement of its compartments, the stomach of *Globiocephalus melas*. My observations have led me to the same conclusion. As the stomach of *Globiocephalus* has been

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Explanation of Figure 1.—Ventral surface of Stomach of Risso's Dolphin. *Oe.*, œsophagus; 1-5, the several compartments of the stomach; *D.*, duodenum; *H.*, hepatic duct; *P.*, head of pancreas; *Sp.*, Spleen.—From a drawing by Harry G. Melville, M.B.

described with considerable detail both by Dr Murie and myself,¹ I need not enter into any lengthy explanation of that organ in Risso's dolphin. I may, however, refer to one or two

¹ *Jour. of Anat. and Phys.*, vol. ii., 1868, and vol. iii., 1869.

points in its morphology. The stomach consisted of five compartments arranged according to the mode of describing the cetacean stomach, which I have followed in a previous paper,¹ into (a) an œsophageal compartment (1); (b) a cardiac compartment (2); (c) two intermediate compartments (3 and 4); (d) a pyloric compartment (5). The œsophageal compartment or paunch (1) was directly continuous with the œsophagus, and was lined by a continuation of its epithelium. It contained several pints of a brown fluid in which the beaks and eyes of cuttle-fish were found—its long diameter was 24 in. (610 mm.), its greatest transverse diameter 14 in. (356 mm.). The 2nd or gastric compartment (2), a true digestive chamber, also communicated directly with the lower end of the œsophagus; it was almost globular in shape, and measured 10 in. (254 mm.) by 9½. It contained the partially digested mantles of 34 cuttle-fish, some of which still had the arms continuous at their bases, also quantities of eyes and beaks. From the relations of compartments 1 and 2 to the lower end of the œsophagus, it is obvious that the food could pass directly from the gullet into either compartment, or from 1 into 2, or be regurgitated from 2 into 1. Compartment 3 was the smallest chamber, and measured 4 cm. by 1½; it was so placed in the angle, between 2, 4 and 5, as to be in danger of being overlooked. Compartment 4 was the size of a large orange. Compartment 5 was elongated, and measured 12 in. (305 mm.) by 5 in. (127 mm.) in greatest breadth; it was slightly sinuous, and had a shallow constriction about one-third the distance from the pylorus, which latter was deeply constricted. The dilated commencement of the duodenum was 12 cm. long, and received on its dorsal aspect the combined pancreatico-hepatic duct.

The *Intestine* from the pylorus to the anus was 76 feet 8 inches long. There was no cæcum or division into a small and a large intestine. The walls were thicker in the anterior half than in the posterior portion. The arrangement of the valvulæ conniventes, the mucous folds of the rectum, and Peyer's patches was so like to what Murie has described in *G. melas* that I need not enter into any detail. The rectum retained its cylindrical tubular form as far as its termination. The muscular coat was

¹ *Jour. of Anat. and Phys.*, vol. xxiii.

much redder at the anal end than further forwards, and the longitudinal arrangement of the muscular coat was distinct. The anal orifice was surrounded by a strong, red-coloured sphincter muscle.

The intestine contained mucus; at the duodenal end it was fawn or salmon coloured; lower down it was bile stained; but in the last few feet it was stained a rich brown colour. From its tint I was led to think that it contained sepia, derived from the ink bag of the cuttle-fish, on which the animal fed. The coloured mucus was then digested in water, when the colouring matter was dissolved. It was then precipitated from the aqueous solution by the addition of spirit, when a rich brown pigment was obtained, possessing the properties of sepia, and which was subsequently used in the preparation of some drawings of the animal's viscera.

From the fact that the mucus, in something like the upper three-fourths of the intestinal tract, was unstained by sepia, it would seem as if the wall of the ink bag had remained unruptured, and its contents undiffused through the mucus, until it had passed along a large part of the intestinal tube.

It has been shown by myself and others that cuttle-fish are a not unusual food for toothed whales. This has long been known as regards *Hyperoodon*, in the stomachs of several specimens of which the horny beaks and other parts of cephalopods have been seen.¹ Mr Beale states² that the food of the Sperm Whale consists almost wholly of the 'squid' or 'sepia octopus,' though at times when near the shore it may take bony fish; Mr Bennett in his *Whaling Voyage*³ confirms the statement that the main food is cuttle-fish, and he also mentions that he has seen a bony fish which was ejected from the stomach of a Sperm Whale on being attacked. From my own dissection I have reason to think that Sowerby's Whale may also feed on cuttle-fish. Mr Robert Gray has repeatedly found the remains of cuttle-fish, probably *Gonatus fabricii*, in the stomach of the Narwhal.⁴ The horny beaks of cephalopods

¹ See Gray's *Catalogue of Whales and Seals*; also my paper on the "Stomach in Ziphioid and Delphinoid Whales" in *Jour. of Anat. and Phys.*, vol. xxiii.

² *The Sperm Whale*, London, 1839.

³ London, 1840.

⁴ *Zoologist*, April 1887 and 1889; in addition he found blood-red crustaceans, mostly *Pasiphaë tarda*, an abyssal form.

were seen by M. Fischer and Mr Lee in the stomachs of the two specimens of Risso's dolphin which they examined. Dr Charles Anderson observed that, as the fishermen opened the stomachs of this dolphin at Hillswick, they contained cuttle-fish; my dissections confirmed this observation. Four of the specimens of the cuttle-fish obtained in the stomach of Risso's dolphin were so far undigested as to enable me to count ten arms projecting from the ring around the mouth. Two of the arms were in three of the specimens much longer than the others, and were separated from each other by two short arms, but the suckers had disappeared in the digestive process. The remains of a pair of wings were attached to the mantle, and I thought that the animals were species of *Loligo*; but Mr W. E. Hoyle, to whom I referred the specimens for identification, regards them as the *Gonatus fabricii* of Lichtenstein. Mr Thomas Anderson has recently communicated to me an interesting fact, which adds another dolphin to the feeders on cuttle-fish. A few months ago a large school of the Pilot Whale (*Globiocephalus melas*) was chased ashore at Hillswick, and on cutting out the viscera the partially digested skins and numerous beaks of these cephalopods were seen in the stomachs. It was also observed that the shallow bay into which these dolphins were driven was strewn with the undigested skins of cuttle-fish, as if the whales in their fright had ejected a portion of the contents of their stomachs.

A number of years ago I described¹ a large cluster of *Lymphatic Glands* in *Globiocephalus melas* at the root of the mesentery, and another cluster close to the lower end of the rectum. Similar collections of glands were seen in Risso's dolphin. One of the rectal glands, about the size of a walnut, was almost completely invested by peritoneum, and projected towards the peritoneal cavity; at first sight it seemed as if it were a special gland associated with the hinder part of the rectum; but when more closely examined, it was seen to be the largest member of a chain of rectal lymphatic glands.

The *Spleen* was attached by a peritoneal fold to the right side of the back of the œsophageal compartment of the stomach. It measured 12 cm. by 6½, but several small accessory spleens were situated in the same peritoneal fold.

¹ *Jour. of Anat. and Phys.*, November 1867, vol. ii. pp. 76, 78.

The *Liver* measured 45 by 28 cm. Its diaphragmatic surface was divided into a large right and a small left lobe by a falciform ligament; in the free edge of which the obliterated umbilical vein formed a round ligament. On the hinder surface of the liver the umbilical vein became pervious for about 5 cm. before it joined the portal vein, with the lumen of which it was continuous. There was no gall-bladder, and consequently no quadrate lobe, neither was there a definite Spigelian lobe. The inferior cava did not groove the liver, but three capacious hepatic veins opened into the cava at the diaphragmatic border.

The head of the *Pancreas* lay in the curve formed by the duodenum and 5th compartment of the stomach, and its opposite end reached the dorsal surface of the 1st compartment. The hepatic duct descended close to the dorsal surface of the pyloric compartment of the stomach, and entered the head of the pancreas, where it was joined by the pancreatic duct. The combined duct formed a sinus-like dilatation, and then pierced the dorsal wall of the dilated commencement of the duodenum.

Genito-Urinary Apparatus.—The hinder end of the peritoneal cavity was prolonged backwards along the rectum. Four cæcal pouches were recognised in connection with it. Two were lateral, and in relation to the testicles, which, invested by peritoneum, projected towards the cavity. Each lateral pouch was prolonged backwards behind the hinder end of the testicle, and its dorsal wall was in relation to the epididymis, whilst its inner boundary was formed by a fold of peritoneum which extended inwards to the side of the bladder, with the peritoneal covering of which it was continuous. Two pouches were mesial; the deeper and posterior was in relation to the rectum, and was separated from a smaller and shallower pouch by a fold of peritoneum, which passed transversely across the mesial plane as far as the free border of the peritoneum, which bounded the pouch situated in relation to each testicle. This shallow pouch lay between the transverse fold and the dorsal surface of the bladder and urethra. If a male uterus had been present, one would have expected to have seen it in this transverse fold of peritoneum.

Testicles.—Each testicle was 16 cm. long, and $2\frac{1}{2}$ cm. in its greatest transverse diameter. In relation to the upper border of each testicle was a large convoluted epididymis, which corresponded to the whole length of the attached border of the testicle, and projected a little beyond its anterior end. The vas deferens emerged from the posterior end of the epididymis. At first it was much convoluted, but in its passage backwards it became almost straight, and gradually approximating to its fellow, it became enclosed in a sheath common to the two. It was situated in relation to the dorsal surface of the urethra, and entered along with it, the compressor prostatae muscle, to be subsequently described. The seminal ducts opened into the dilated prostatic part of the urethra, and their position was marked by a distinct longitudinal urethral crest. There was no appearance of a vesicula seminalis.

The *Kidneys* possessed the usual subdivision into lobules found in the Cetacea.

The *Bladder* was elongated, and when distended with air was 20 cm. long, and 7 cm. broad at its widest; it ended behind in a funnel-shaped prolongation, which was continued into a membranous cylindriform urethra. The two ureters opened into the superior surface of the bladder, a little in front of the urethra. The hypogastric arteries ran at the sides of the bladder as far as its apex, where they came into relation with the urachus, and along with it passed forwards on the abdominal wall.

The cylindriform part of the urethra ran backwards for 90 mm. and then entered the anterior end of what seemed to be a thick mass of muscle, 68 mm. in antero-posterior and 60 mm. in transverse diameter. This muscle completely surrounded both the urethra and the seminal ducts; it occupied the interval between the inter-pelvic ligament, which was on its ventral surface, and a strong recto-prostatic fibrous membrane, situated in close relation to its dorsal surface, which intervened between it and the rectum. The fibres of this muscle sprang laterally and ventrally from the inter-pelvic ligament, and arched in a forward direction to the dorsal surface of the mass, where the fasciculi from opposite sides seemed partly to blend with each

other, and partly to end in a median fibrous septum. When this muscle was cut into, it was seen to enclose a fawn-coloured body, into the substance of which both the urethra and seminal ducts penetrated. Both in colour and appearance this body

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Explanation of Fig. 2.—Dorsal surface of Bladder and Urethra. *B*, bladder; *u*, ureter; *ur*, urethra; *vv*, vasa deferentia; *p*, pelvic bone; *ip*, interpelvic ligament; *cp*, compressor muscle of the prostate; *ra*, *ra*, retractor ani muscles, the tendon of origin of that on the right side is cut through and turned on one side.—From a drawing by W. Aldren Turner, M.B.

was obviously not composed of striped muscle, like the muscle by which it was surrounded. It had a granular texture, and when examined microscopically was seen to consist of gland

acini, containing cells, and bands of what seemed to be non-striped muscular fibre with connective tissue. Both in its position and relations to the rectum and inter-pelvic ligament, and in its structure, it may be regarded as a *prostate gland*. It is to be observed that it did not surround the neck of the bladder, but was some centimetres removed from the spot where the bladder and urethra were continuous with each other. The walls of the urethra when surrounded by the prostate were thin, and its lumen was dilated. Immediately on leaving the prostate the urethra pierced the inter-pelvic ligament, and turned sharply forwards into the corpus spongiosum.

The muscle which enclosed the prostate gland would, from its arrangement, act as a compressor of that gland and of the urethra and seminal ducts enclosed within it, and it may be called *compressor prostatae*.

Pelvic Bones, Inter-pelvic Ligament, and Pelvic Muscles.—The most complete account of these structures in the Cetacea will be found in the very careful descriptions by Dr Struthers of the pelvic apparatus in the Greenland whale (*Balaena mysticetus*)¹ and the hump-backed whale (*Megaptera longimana*).² In dissecting the corresponding parts in the male Risso's dolphin, his descriptions and drawings were before us.³ But as it was found that in various particulars the arrangement of parts in the dolphin differed from what Dr Struthers had seen in the whalebone whales, I have thought it advisable to write a description of these structures.

Each *pelvic bone* consisted of an almost straight bar, somewhat pointed at its two ends. Its length was 108 mm., and its greatest breadth was 14 mm. Its upper surface was flattened, and its lower surface was somewhat convex from side to side. No trace of a rudimentary femur was connected with it.

The *Inter-pelvic Ligament* was a strong fibrous membrane, which stretched between the two pelvic bones, and was attached to their inner borders for a little more than the anterior half of their length. It formed a distinct partition, on the perineal

¹ *Journal of Anat. and Phys.*, vol. xv., 1881.

² *Ibid.*, vol. xxii., 1888.

³ In making these dissections I have been very materially assisted by one of my pupils, Mr J. R. Higson.

(ventral) aspect of which was the penis with its muscles and on the dorsal aspect were the prostate with the urethra and genital ducts and the rectum. Its posterior border was thickened and continuous with a strong recto-prostatic fascia, which was situated between the rectum and the powerful compressor prostatae muscle. This border was indented in the mesial plane, to allow of the lodgment of the retractor penis muscle. The anterior border was free near its pelvic attachments, but nearer the mesial plane it was fused with the fibrous tissue of the corpora cavernosa penis.

The Penis.—The penis arose by two short crura. Each crus, pointed posteriorly, sprang from the ventral surface of the pelvic bone in its posterior part for a distance of 31 mm., but did not quite reach the posterior end of the bone. The crura were also intimately united with the perineal surface of the inter-pelvic ligament, and near the anterior border of which they joined to form the body of the penis. The length from the point of the crus to the orifice at the end of the glans was 325 mm. The two corpora cavernosa were firmly united, and so overlapped the corpus spongiosum on the ventral surface of the organ that it was only partially seen. The glans, 95 mm. long, was elongated and tapered almost to a point at the urethral orifice. It was concealed by the prepuce and the genital slit in the abdominal wall.

Retractor Penis.—A well-marked retractor muscle was situated on the middle of the ventral surface of the penis. It consisted of two lateral halves, closely united together by areolar tissue, and formed an elongated, somewhat flattened, thick, pale band of non-striped muscle, which was inserted anteriorly into the penis at the root of the prepuce. When followed backwards it was seen not to be adherent to the corpus spongiosum. When midway between the two pelvic bones it pierced the accelerator urinæ muscle, passed behind the middle of the posterior border of the inter-pelvic ligament, and was then attached to the muscular wall of the rectum and the recto-prostatic fascia.

Ischio-cavernosus.—This powerful muscle arose from the ventral surface and outer border of the whole length of the pelvic bone except at its anterior end. It completely concealed the crus penis, into which it was inserted, but it was also pro-

longed for a short distance forwards, to be inserted into the side of the corpus cavernosum penis. The most anterior fibres did not, however, pass in front of a transverse plane drawn between the anterior ends of the two pelvic bones, so that its insertion was limited to the hinder part of the penis.

Accelerator Urinae.—This muscle occupied the interval be-

Explanation of Fig. 8.—Ventral Surface of root of Penis with its Muscles. *cc*, corpus cavernosum, and *cs*, corpus spongiosum penis; *RP*, retractor penis muscle; *P*, anterior end of left pelvic bone; *IsC*, ischio-cavernosus muscle; *AU*, accelerator urinae muscle.—From a pen-and-ink sketch by Dr James Musgrove.

tween the posterior halves of the two ischio-cavernosi. It consisted of two symmetrical halves, separated by a mesial interval. They were traced back close up to the muscular mass of the sphincter ani, and formed posteriorly a loop around the retractor penis. The fibres passed forwards from this loop to surround the

bulb of the urethra, and some were inserted into the perineal surface of the inter-pelvic ligament; but the most anterior fibres were inserted into the corpora cavernosa as far forward as about the middle of the insertion of the ischio-cavernosus muscle.

Retractor Ani.—A well-marked muscle, which arose from the dorsal surface of the anterior end of the pelvic bone by a strong and somewhat rounded tendon. It passed backwards in relation to the dorsal surface of the inter-pelvic ligament as far as its posterior border, from which it received an additional slip of origin. It was then prolonged backwards, to end in the muscular mass of the sphincter. From the presence of this pair of muscles it is probable that the dolphin, like the horse, protrudes the anal mucous membrane in the act of defæcation, and that the function of these muscles is to retract it on the completion of the act. The muscles are red and transversely striped. They are probably to be regarded as special modifications of the levatores ani of the anthropotomist.

A fragment of a muscle was attached by a strong tendon to the anterior end of the pelvic bone, but as its connections in front were not preserved, I cannot describe it. No muscle was seen to be attached to the posterior end of the same bone.

THE MINUTE ANATOMY OF THE CENTRAL NERVOUS SYSTEM, ACCORDING TO GOLGI'S METHOD.

1. Sur la structure de l'écorce cérébrale de quelques mammifères, par S. Ramón y Cajal. *La Cellule*, tome vii. fasc. 1, p. 125.
2. La structure des centres nerveux ; la moelle épinière et le cervelet. Par A. van Gehuchten. *Ibid.*, p. 81.
3. Verhandlungen der Anatomischen Gesellschaft, Mai 1891, containing an Address by Professor A. von Kölliker on this subject.

(Translated and Abstracted by WILLIAM ALDREN TURNER, M.B. (Edin.), M.R.C.P. (Lond.).)

THE method adopted by Golgi for the examination of the central nervous system gave such striking and novel results that anatomists were slow in accepting many of the facts. Much work has, however, been done recently with a view to confirm his experiences, mainly by Ramón y Cajal of Barcelona, Martinotti, Sala, v. Lenhossek, and von Kölliker. The confirmatory observations of Kölliker have been communicated in this Journal (vol. xxv. p. 443). A brief resumé of what is now known regarding the minute anatomy of the spinal cord and brain will be given, based upon the two important contributions in "*La Cellule*," and upon Professor Kölliker's address before the Anatomical Society in Munich.

1. *The Cerebral Cortex.*

Ramón y Cajal has examined the cortex in small mammals (rats, rabbits, &c.). He divides it into four layers. *First, or molecular layer.*—This the most superficial layer, is composed of nerve fibres, nerve cells, and the protoplasmic expansions of the subjacent pyramidal cells. The nerve fibres are extraordinarily abundant, and run parallel to the surface of the cortex ; some of them have been observed to pass into the subjacent layers, and become continuous with axis-cylinder processes. Of the nerve cells three kinds have been described :—(a) Polygonal cells, not numerous, and possessing protoplasmic processes which pass off in all directions. (b) Fusiform cells ; these he found lying in a horizontal antero-posterior direction. They have only two protoplasmic processes, one from either pole. Owing to their great length it is almost impossible to follow out their whole course, but they bend and end free under the surface of the cortex. The axis-cylinder processes (for there may be two or three of them) arise from the protoplasmic expansions at a considerable distance from the body of the cell. They give off at right angles numbers of ascending collaterals, which end free in this layer. It is not uncommon to find a supernumerary axis-cylinder. The fusiform cells

are not numerous. (c) Triangular cells; these are much more plentiful than the preceding; of the three branches which each cell gives off, one is descending and bifurcates. There are two, three, or more axis-cylinder prolongations, which always arise from the protoplasmic processes. Some pass to the surface of the layer, and others terminate free. The protoplasmic expansions of subjacent pyramidal cells ramify to a considerable extent in this layer, and end under the free surface. There are also oblique and arciform branches which end in different parts of this layer. Here, then, is an arrangement similar in all respects to that which obtains in the molecular layer of the cerebellum. In his previous works Ramón y Cajal had considered the protoplasmic processes not as absorbers of nutrition, but as the means of communication of nervous action between neighbouring cells and elements at a distance. In applying this principle to the molecular layer of the cerebral cortex, one observes that the fusiform and triangular elements, by means of their multiple axis-cylinder prolongations and very long protoplasmic expansions, are in contact with and intermix with a great number of the terminal protoplasmic processes of the subjacent pyramidal cells. It is not unlikely that some of these may functionate by contact. It is on this supposition that the term "association cells" has been given to the elements of the molecular layer.

Second layer (layer of small pyramidal cells).—In mammals these cells are not proper pyramids, but are polygonal or star-shaped. The protoplasmic processes pass off from the upper and lateral angles, and terminate in the molecular zone. The axis-cylinder descends, but its termination is yet the subject of much investigation. The author states that he has traced it into the white matter, and onwards into the corpus striatum (from cells in the frontal lobes), and into the corpus callosum (from cells in the Rolandic area). In their course they give off collaterals.

Third layer (layer of large pyramidal cells).—This layer passes insensibly out of the previous one. In mammals it resembles that of man, except that the cell bodies are less pyramidal and more ovoid, and the protoplasmic processes are shorter. The axis-cylinder descends in a straight line into the white matter, where it becomes continuous with an association or projection fibre. It gives off many collateral branches, which assume a horizontal and oblique course, and end near the molecular layer. Nearly all the collaterals end in a small expansion without any branching.

Fourth layer (layer of polymorphic cells).—The cells are mainly globular, but some are fusiform, and of various pyramidal types. They all have ascending and descending protoplasmic processes, the former of which end in the middle layer of the cortex, the latter in the white matter. The greater number of axis-cylinder expansions descend and give off fine collateral branches, which end as a delicate fibril in the white substance. This layer is in contact with the white fibres.

Scattered throughout these layers are certain other elements which require description:—1. *The sensory cells of Golgi*.—They are met

with in all the layers, but mainly in the fourth or deepest zone. Their protoplasmic processes pass off in all directions, and are of considerable length, but they do not reach the molecular layer. The axis-cylinder descends, has a short course, and ends free in a complex ramification. Ramón y Cajal does not hesitate to disprove their sensory nature, as advocated by Golgi; he inclines to the view that they are "association cells." 2. *Cells with an ascending axis-cylinder.*—They are triangular, and lie amidst the small pyramidal cells. The axis-cylinder enters the molecular layer. Here it divides into horizontal fibres of great length. But all the cells are not prolonged so far as this layer; a similar disposition of branches takes place also in the second and third layers. 3. *White fibres, which ramify in the grey matter.*—These are amongst the largest fibres which cross the cortex. They are larger than the axis-cylinder process of the large pyramidal cells. They penetrate the cortex at a right or obtuse angle, and divide into two or three large branches. These repeatedly divide, and end in the layers of small and large pyramidal cells. These fibres never anastomose with other fibres in the grey matter, nor do they terminate in cells. The author cannot confirm Golgi's belief that they are sensory. 4. *The nerve plexus of the grey matter.*—The intervals between the nerve cells are filled in by varicose fibres, formed by collaterals of the pyramidal and polymorphic cells, by the terminations of the sensory cells of Golgi, by the collaterals and terminals of the cells having an ascending axis-cylinder, by the collaterals of the association fibres of the white matter, and by the collaterals and terminals of the fibres coming from distant central organs, and from the corpus callosum! The enormous complexity of the nerve network of the grey matter is sufficiently apparent from this description. No idea of the innumerable ramifying fibres in the cortex can be obtained by the Weigert-Pal method.

The white matter. 1. *Fibres proper to the cortex, or association fibres.*—The axis-cylinders of the cortical cells are continued into these fibres, either by simple bending at a right angle, or by dividing into a T or Y in the white matter; the branches of bifurcation pass in opposite directions. After some distance the fibres turn back into the cortex, and end by dividing. In the outer part of the hemispheres the fibres change their direction and form a large transverse descending tract—the fasciculus transversalis. When the fibres above mentioned divide into a T or Y, one of the branches goes to the corpus callosum. The association fibres give off collaterals, which pass at a right angle into the cortex, behaving just as the collaterals of the column fibres of the spinal cord. The presence of collaterals of the white fibres of the brain is now a well-known fact. 2. *The corpus callosum.*—The fibres of this structure have a horizontal course in the middle portion, but laterally they are ascending. They maintain their parallelism until they reach the subcortical white matter, where they bend amongst the arcuate fibres, and pass into the grey substance. They give off collaterals, which also pass into the cortex. It is not yet certain how these fibres commence or terminate. Some appear to be direct continuations of axis-cylinder processes; others

are collaterals of the axis-cylinders of projection and association fibres. Their terminations are probably delicate ascending fibrillæ, which are found distributed through the middle and lower layers of the cortex. 3. *Projection fibres*.—These are the direct continuations of the pyramidal and polymorphic elements of the cortex. They give off a great number of collateral branches. They pass into the corpus striatum, where many are seen to give off very fine ramifying branches, which end in the cells of this ganglion.

Some general conclusions are worthy of note. One cannot tell by any special morphological character cells whose axis-cylinder constitutes either an association, a projection, or a commissural fibre. No direct anastomoses are observed between the nerve fibres of the grey matter. Transmission of nerve impulses must therefore be carried out through contact. The human cerebrum owes its superior activity not only to the great number of its cells, but to the extraordinary richness of its association paths—i.e., the collaterals, axis-cylinder, and protoplasmic expansions.

The Cerebellum.

Van Gehucten describes the *granular layer* as composed of three kinds of cells—small and large nerve cells and neuroglia cells. Each small cell has a polygonal body, from each angle of which there passes a protoplasmic process, which ends freely in a tuft. The axis-cylinder rises from a protoplasmic process, and passes towards the molecular layer, where it bifurcates; its divisions end free. The large cells are met with in close relation to the cells of Purkinjé. They have many protoplasmic processes, some of which pass to the surface of the cerebellum. Others are horizontal, and end in the granular layer. The *molecular layer* is rich in small cells. They give off protoplasmic processes, which pass upwards and downwards, while the axis-cylinder expansion assumes a horizontal course. Some of the collaterals of this pass to Purkinjé's cells, which they envelop in a tuft, the so-called *Korbzellen* or basket cells of Kölliker. The protoplasmic processes of *Purkinjé's cells* extend into the molecular layer; the axis-cylinder courses through the granular layer to the white matter.

Further study of the cerebellum has given rise to the same general conclusions regarding it as in both the cerebrum and the spinal cord. The true nerve element is the cell with its prolongations. The nerve elements are independent of each other, the protoplasmic processes end free, and, whatever its disposition, so does the axis-cylinder. Finally, the transmission of impressions here, as throughout the cerebro-spinal system, takes place not by continuity, but by contiguity or contact.

The Spinal Cord.

Van Gehucten has paid special attention in the cords of small mammals to certain points which were still *sub judice*. Firstly, the relation of the anterior nerve roots to the cells of the anterior nerves. Each anterior nerve root is the axis-cylinder prolongation

of a cell. The protoplasmic processes of these "root cells" are numerous, and form an inner group, which passes by the anterior commissure to the opposite anterior horn; an antero-external group which passes to the periphery of the grey matter; and an antero-posterior group which passes into the grey matter.

The author's researches upon the posterior roots support the statements of Kutschin, Freud, and Klausner that some of these root fibres have their origin in cells in the grey matter of the cord. This is opposed to the views of Golgi, Ramón y Cajal, and Kölliker. The great majority arise from cells in the posterior ganglia, and divide into ascending and descending branches. Both give off collaterals, which pass into the grey matter. A great many of these branches end in close relation to the cells of Clarke's column. Many of the fibres themselves end free in the grey matter at all levels of the cord, but others terminate in the nuclei of Goll and Burdach. The longitudinal fibres of the antero-lateral column behave just as those of the posterior—i.e., that at variable distances they give off collateral branches, which pass into the grey matter and end free. All the nerve fibrillæ in the grey matter form a complex network. They remain quite independent of each other. Collaterals of the lateral column fibres have been seen to cross by the posterior commissure, and end in the grey matter of the opposite posterior horn.

The study of the structure of the spinal cord confirms what Golgi originally noted—that the cells do *not* anastomose through their protoplasmic processes. Each cell with its processes forms an independent autonomous structure. His has shown from his embryological studies that every nerve cell, with its processes, is formed by the transformation of a neuroblast. Nerve cells vary immensely in size, form, and richness of processes; but there is one constant structure, the axis-cylinder prolongation. It arises directly from the body of a cell, or from one of the expansions. It is distinguished by the cleanness of its contours and its regular course. It retains an unaltered diameter for a long distance; it bifurcates and gives off collaterals. It terminates blindly in one, two, or more branchlets. One can therefore divide these elements into two main sets—one occupying the top of the cerebro-spinal axis, whose process conducts centrifugally; and the other the lower part, whose process conducts centripetally. But an intermediate class exists, whose axis-cylinder process bifurcates and conducts upwards and downwards ("mixed cells"). An important fact in nerve physiology is therefore confirmed—that the axis-cylinder process of a nerve cell is a conductor, conveying any form of impression, and transmitting it, by collaterals or terminals, to corresponding structures with which it comes in contact.

Notices of Books.

Annual of the Universal Medical Sciences, a Yearly Report of the Progress of the General Sanitary Sciences throughout the World. Edited by Charles E. Sajous, M.D., and Seventy Associate Editors. Illustrated with chromo-lithographs, engravings, and maps. Philadelphia: F. A. Davis, 1891.

WE have again to acknowledge the receipt of this the most complete Annual of the Medical Sciences, which is as admirably prepared as any of its predecessors. It has now reached its fourth year of issue; and if the vigour and energy which have characterised the preparation of this and the three previous series be continued, we may predict for it a life of prolonged usefulness. The departments of Anatomy, Physiology, and Embryology, which are of more especial interest to our readers, have received a fair share of space, although, as may only properly be looked for in a work which appeals more especially to the practitioner, they do not occupy so large a proportion of pages as is given to the subjects which have a more direct bearing on medical and surgical practice.

A Guide to Operations on the Brain. Illustrated by 42 life-size plates in autotype, and 2 woodcuts in the text. By Professor Alec Fraser. London: J. & A. Churchill, 1890.

PROFESSOR FRASER has called in the aid of photography to illustrate the anatomy of the brain. His object has been to show the organ *in situ*, and to determine the relations both of the convolutions on its surface, and of the more deeply lying parts, to the exterior of the skull and the scalp. The author describes the methods which he has pursued to harden the brain in its place, and to fix on the surface of the head graduated tape-lines, which will give definite measurements in certain directions. He then describes his method of embedding the head which he is studying in plaster of Paris, and the steps which require to be pursued in order to obtain a series of photographic negatives of dissections in various planes from the surface inwards, which may afterwards be combined into composite photographic plates. The author then gives a description of the relations of the most important parts of the brain to the surface, and concludes

his text with a bibliography and short history of the various methods that have hitherto been employed in elucidating the relations of the cortex to the cranial vault or to the scalp. The plates furnish a very remarkable series of views, and enable the anatomist and surgeon to acquire a much more vivid conception of the surface relations of the brain than can be found in any previous writings on the subject. The work is one which has obviously been of great labour, and could only have been executed by a skilled anatomist, willing to give much time and money to the prosecution of the object which he had in view.

The Comparative Anatomy of the Domesticated Animals. By A. Chauveau, M.D. Revised and enlarged with the co-operation of S. Arloing. Translated and Revised by George Fleming, C.B., LL.D. With 585 illustrations. London: J. & A. Churchill, 1891.

DR CHAUVEAU'S treatise on the *Anatomy of the Domesticated Animals* has, since its first appearance in Paris in 1857, been known as one of, if not the best, book on the subject. In 1874, Mr George Fleming, so well known as one of the most accomplished veterinarians in the country, published an English translation of the book, and in the present year he has produced a revised and enlarged edition, so as to bring it up to the present date. In this edition the anatomy of the ass, mule, rabbit, and camel have been considered, in addition to that of the animals described in the preceding edition. Numerous additional woodcuts have been inserted into the text, making in all 585 figures, so that for completeness and utility Fleming's translation of Chauveau will undoubtedly take a first place in the library of the veterinary student.

The Tribes and Castes of Bengal. By H. H. Risley, Indian Civil Service; Anthropometric data. Vols. i. and ii. Calcutta, Bengal Secretarial Press. 1891.

MR RISLEY has for a number of years been engaged in taking measurements of the heads of the various tribes and people in Bengal, the North-Western Provinces of India, and the Punjab. The instruments which he employed were those recommended by Dr Paul Topinard in his *Éléments d'Anthropologie Générale*, and (with the exception of the naso-malar index, which was calculated after the manner described by Mr Oldfield Thomas in the *Journal of the Anthropological Institute*, May 1885) Dr Topinard's methods of measuring and calculating indices were followed throughout.

The two volumes contain many thousands of measurements of the height and width of the nose; the bi-malar and naso-malar breadth; the cephalic length and breadth; the minimum frontal breadth; the maximum bi-zygomatic breadth; the height from vertex to super-

ciliary point, from vertex to tragus, and from vertex to chin; the stature and weight, and the facial angle. The following indices are calculated from the measurements:—Nasal, naso-malar, cephalic, fronto-zygomatic, vertico-cephalic, vertico-bimalar, vertico-frontal, vertico-bizygomatic, and height and weight.

No descriptive letterpress accompanies the tables of measurements, but the author promises a full analysis, showing their bearing upon the ethnology of Northern India and upon more general questions, in a separate volume. To some extent probably the paper read by the author at the British Association meeting in Newcastle-on-Tyne, 1889, a brief abstract of which was published in the *Transactions of Sections*, p. 785, furnishes an indication of the author's conclusions.

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Journal of Anatomy and Physiology.

THE MYOLOGY OF THE LARYNX. By A. A. KANTHACK,
John Lucas Walker Student, Cambridge University.
(PLATES VI, VII.)

IN a research (25) on the histology, normal and pathological, of the larynx, my attention was attracted to the arrangement of its muscular fibres. Most anatomists have dissected the various muscular bundles attached to the laryngeal cartilages, and have then described each group of fibres thus separated as a special muscle. This method is eminently confusing. Merkel (17), for example, divides a single muscular mass (Thyreo-arytænoideus internus et externus) into seven parts, giving each of them a separate Latin name. Henle's method (1, 2, 3) is more satisfactory. From a consideration of the reptilian and amphibian types, he regards as a whole (sphincter) the MM. arytenoideus obliquus and transversus, thyreo-arytenoideus internus and externus, and the crico-arytenoideus lateralis. M. Fuerbringer (10), in his exhaustive monograph, disagrees with Henle's views, basing his arguments on embryology and comparative anatomy.

In what follows, I propose to give a simple account of the myology of the larynx, describing only the usual arrangement, and neglecting abnormalities.

General Method.

The method employed was as follows:—The whole larynx was embedded in celloidin. Microscopic sections, arranged in numerical series, were made from larynxes of all ages. Uniform results were thus obtained after the examination of more than fifty specimens. At my disposal were larynxes of two months foetuses, four months foetuses, foetuses from five to seven months, new-born children, children from one to four years, and of a few

adults. Having convinced myself that no difference exists in the minute muscular arrangement of adults and infants, I chiefly examined the latter, as easier to manipulate, and as giving a clearer and more comprehensive view. The plane of the sections was mostly horizontal, in some cases coronal or sagittal, or even oblique.

Developmental Considerations (figs. 1, 2, 3).

The respiratory apparatus is primarily developed from the foregut, and hence we may expect that at an early period of development there is a close muscular continuity between the pharynx and larynx. At the second month there is a continuity between the fibres of the Constrictor pharyngis and the horizontal fibres surrounding the larynx, so that at this age we may in a certain sense speak of a great circular muscle surrounding the larynx and pharynx. In the earliest embryo which I have examined (two months), branches are given off laterally from this large muscular ring, and pass inwards to join the smaller intrinsic ring to be described below. The outer larger ring represents the mass of the Constrictores, Stylo-pharyngei, Crico-thyreoidei, &c.

On examining the intrinsic ring, we find that (*a*) the thyreo-arytænoid muscle is but slightly developed at the second month, the other muscles (*i.e.*, Interarytænoideus and Crico-arytænoideus posticus) being well marked; (*b*) there is undoubtedly a close connection between the Interarytænoideus and the Thyreo-arytænoideus; (*c*) it is impossible, as Disse has already pointed out (6), to separate the Thyreo-arytænoideus from the Crico-arytænoideus lateralis. This holds both in the child and adult. The intrinsic muscles have, at least up to the fourth month, the same direction, so that in this manner we have an inner smaller ring within a larger one. This inner ring represents the Thyreo-arytænoidei, Crico-arytænoidei laterales and postici, and the Interarytænoideus. At the second month, however, it is impossible to separate the two latter muscles. In the four-months foetus, at the inferior cornu of the thyroid cartilage, the Crico-thyreoideus comes in close contact with the Constrictor, so that at this stage it is impossible to separate one from the other. The mesial fibres of the Crico-thyreoideus have the same direction as the

remaining intrinsic muscles of the larynx which may be considered in the light of a sphincter.

The question now arises, Is the idea of a sphincter tenable from an embryological as well as from a physiological standpoint? On comparing figs. 1-3 we find that the Interarytænoideus sends fibres forwards, though these form only a small mass; that, again, this muscle is directly continuous with the Crico-arytænoideus posticus; and the latter, again, with the Cricothyreo-arytænoideus of Cruveilhier (12). Hence, although this whole mass presents varying thicknesses at different levels, it may, as Henle suggests (*loc. cit.*), be regarded as a sphincter. The subsequent partial disappearance of this sphincter-like arrangement is, in my mind, due to two factors—(i) the development of the larynx in a vertical direction, and (ii) the increased growth of the arytaenoid cartilages, which thus contract muscular attachments. For by the fourth month gradually a differentiation of the muscles takes place,—changes in the direction of the fibres being caused by the changes in the relative positions of the cartilages. These alterations, as Fuerbringer (*loc. cit.*) remarks, are

“easily explained by the growth of the thyroid cartilage, more especially in the vertical direction. For while this cartilage in the early foetus is comparatively of only moderate length, its subsequent growth in length is more marked than that in breadth, the upper part of the cartilage growing more rapidly than the lower, until it reaches its full development in the adult.”

The insertion of the muscles at the processus muscularis remains unchanged, while the attachment to the thyroid cartilage moves up. It is as though the larynx had expanded upwards and downwards, the plane of the cords remaining fixed. Hence it is that the fibres in this fixed plane remain straight and horizontal, while the others run either obliquely downwards or upwards. For we see macroscopically as well as microscopically (best in a five-months foetus) that while a part of the Interarytænoideus and Thyreo-arytænoideus presents a straight and horizontal course, the other fibres of these muscles run partly obliquely upwards, partly downwards.

I must here mention, that since this paper was written, I have met with an article by Dr Strazza (11), and I find, with

pleasure, that my results derived from examining very early fetuses entirely agree with his, as far as the myology of the larynx is concerned. His paper was published in 1888.

The Musculature of the Adult Larynx.

After these preliminary observations on the condition of the muscles in the embryo, we proceed to consider the musculature of the adult larynx, and in the following description the course of the fibres will be traced, as though they arose at the posterior or dorsal parts of the larynx, as this simplifies matters considerably.

(1.) *Musculus Interarytænoideus.*

Neglecting the coarse anatomical insertions, attention will be paid to the direction of the fibres. In all systematic works on anatomy two parts are distinguished—(a) a purely transverse one, and (b) an oblique one. Thus Henle (*loc. cit.*) separates this muscle into two, viz., the Transversus and a muscle which, on account of its connection with the Crico-thyreo-arytænoideus, he called the Thyreo-ary-epiglotticus. That this division, however, is quite artificial, the microscope proves beyond all doubt. Fuerbringer (*loc. cit.*) also speaks very decidedly on this point:—

“Both muscles are so closely connected that their separation according to the direction of the fibres is an artificial result of dissection; and though the superficial fibres of the Transversus show a somewhat oblique course, yet a separation is quite impossible.”

Generally the anterior or ventral fibres extend transversely or horizontally from one arytænoid cartilage to the other. In young embryos (three to four months) these fibres arch around the “post-arytænoid sinus,” which I described in former papers (25), and thus do not run straight across, but later, when this sinus is not well marked, they extend straight from one side to the other.

The more posterior or dorsal fibres of the Interarytænoideus are not horizontal, but, coming from the outermost part of the arytænoid cartilage, they are directed obliquely upwards and decussate behind the transverse part of the muscle with the corresponding fibres of the opposite side (figs. 4, 4a, 5, 6, 7). The transition from the straight to the decussating fibres is a

gradual one, and at times we may see the decussation in both parts of the muscle. The most external or lateral fibres of this muscle have no attachment at the cartilages. The most superficial or dorsal fibres can be traced further in the lateral walls of the larynx:—

- (a) The uppermost fibres run to the cartilages of Santorini (to form the so-called *Musculus cartilaginis Santorini*).
- (b) The intermediate fibres run partly independently and partly with the uppermost fibres of the *Thyreo-arytænoideus* in the ventricular bands, the former being found chiefly between the ventricle and the thyroid cartilage, the latter chiefly on the mesial aspect of the ventricle (figs. 5 and 6).
- (c) The lowest fibres blend altogether with those running in the *crista vocalis*, i.e., *Thyreo-arytænoideus* and *Crico-arytænoideus lateralis* (fig. 7).

This close connection between the *Interarytænoideus* and the *Thyreo-arytænoideus* was first insisted on by Henle (*loc. cit.*). Fuerbringer (*loc. cit.*), however, expresses himself as follows:—

“From the standpoint of development and comparative anatomy, it may be proved that this (i.e., the superficial) layer of muscles is not originally laid down, but secondarily developed from a special development of the superficial fibres of the *Thyreo-arytænoideus* and the *Interarytænoideus*.”

In the youngest embryo, however, I find that the *Interarytænoideus* sends fibres into the lateral walls of the larynx, and there is therefore a primary connection and continuity between the *Interarytænoideus* and the *Thyreo-arytænoideus*. I agree, then, with Henle in considering the mass of the *Interarytænoideus*, *Thyreo-arytænoideus*, and *Crico-arytænoideus* as corresponding to the sphincter of the reptiles and amphibia; and I consider it quite an artificial procedure to separate a number of strata. A *Thyreo-arytænoideus internus* and *externus* can be distinguished as little as Merkel's seven strata (*loc. cit.*), or the various muscles of Luschka (4), or the three of Fuerbringer (*loc. cit.*), with their many aberrations of origin and insertion. Microscopical results forbid such analyses, which besides are highly confusing. This muscular mass, as even Merkel and

Fuerbringer acknowledge, forms an uniform complex ; why not, therefore, describe it as such ?

(2.) *Musculus Thyreo-arytænoideus.*

Disse (6 and 7) first, and after him Fuerbringer (*loc. cit.*) and Jacobson (5), have denied the assertion of Harless (13), Merkel (17 and 18), Luschka (4), Ruehlmann (16), and others, that it is possible to separate this muscle into two parts, *i.e.*, a so-called "vocal cord muscle" (Stimmbandmuskel), or internus and an externus. The microscope teaches that the muscle is one and indivisible, and that, moreover, it cannot be separated from the Crico-arytænoideus lateralis, as far as direction and connections go. To be quite accurate, it must be mentioned that Henle (*loc. cit.*) had repudiated this division into an externus and internus, and that Cruveilhier (12), and after him Merkel (*loc. cit.*), hinted at a Crico-thyreo-arytænoideus ; but it was Disse who first entirely grasped the indivisibility of this muscular mass. He says:—"We should consider the Crico-arytænoideus lateralis the second head of the Thyreo-arytænoideus, on account of the close connection of the fibres at their insertion."

On this point I have on a former occasion (27) examined the cords of more than twenty adults, recently of a large number of newly-born infants, foetuses, and children. The sections were mostly horizontal, as this seemed the best method, for in coronal sections, on account of the obliquity and curve of the cords, it is quite impossible to cut one and the same cord in all sections vertically to its free border ; in fact, most of the fibres are divided obliquely, and this may easily lead to grave fallacies.

It is naturally very difficult, after having analysed so complicated a muscle, to build it up again. I believe that all claims will be fulfilled, if its chief component parts be described. At the outset, I must unfortunately disagree with Dr A. Jacobson (St Petersburg), who gives us a lengthy description of this muscle, under the title "Zur Lehre vom Bau und der Funktion des Musculus Thyreo-arytænoideus beim Menschen" (5), and has come to the conclusion that there are oblique and straight fibres which penetrate the substance of the cord, like oblique teeth of a comb, and insert themselves at the margin of the "chorda." The dispute as to the insertion is a very old one.

Ludwig (20), Harless (13), Koelliker (21), Henle, Hermann (22), and Ranke (28) decided for an insertion of muscular fibres into the cord itself; while Verson (15), Luschka (4), and Ruehlmann (16) became the chief representatives of the opposite view. According to Ruehlmann's investigations, no muscular fibres are attached to the elastic tissue of the vocal band (chorda), but an insertion takes place below the rima glottidis into the "cord, in the wider sense of the term." It is unnecessary to quote *in extenso* the views of the various authorities, but enough has been said to show how they differ on this point. Jacobson's monograph (5) is the latest on the subject I had access to.

In my opinion there is only one means of deciding this question, viz., to cut cords as fresh as possible in serial sections, and to examine each one microscopically for any insertion of muscular fibres into the tissue of the chorda. Muscular fibres at their insertion pass by transition into fibrous (or elastic) tissue; hence, this appearance may be considered as a criterion of the insertion of a muscle [Koelliker]. Fresh unstained specimens are to be treated with glycerin or strong caustic potash. The relation of the fibres and the perimysium to the elastic tissue of the cord can thus be accurately observed.

A real insertion can easily be made out at the receding angle of the thyroid cartilage, and also behind, into the arytaenoid cartilage and its processus vocalis. These, then, are typical "immediate tendinous insertions." In unstained specimens the optical differences are much better marked than in stained ones, especially when such staining has been obtained with the opaque hæmatoxylin. And since optical differences are of the utmost importance in deciding the point at issue, unstained preparations were employed. I may say at once that in this manner I have convinced myself of the truth of Luschka's and Verson's descriptions, viz., that *an insertion never takes place either (i) into the chorda or (ii) even below it*, as Ruehlmann (16) declares. For if the fibres running nearest the cord are examined, no transition of striped muscular fibres to the elastic tissue, nor any connection between the latter and the perimysium internum, is visible. But the optical differences clearly show that these tissues do *not* blend, and that an interval *always* exists between

them. An oblique section or shrinking of the tissues often resembles an insertion.

An independent description of the direction of the fibres of this muscle will now be given. There is in the Thyreo-arytænoideus a large muscular mass, which forms with the Crico-arytænoideus lateralis an entire system. Still I consider it for the present advisable to keep these two muscles apart. Three sets of fibres can be distinguished in the Thyreo-arytænoideus according to their direction, but to give these special names is entirely artificial and confusing. The fibres are so closely blended and interwoven, the transition from one direction to the other so gradual, that a natural division into parts is out of the question.

- (a) The *middle* portion of this muscle, which corresponds to the vocal cord, is more or less horizontal, and it is so in its whole expanse, *i.e.*, from the free margin of the cord to the thyroid cartilage, so that it is quite impossible to speak of an "internus and an externus" at this level. These fibres converge, as they extend forwards to be inserted into the angle formed by the alæ of the thyroid cartilage (figs. 7 and 8).
- (b) The *upper* portion is directed upwards and forwards from the arytenoid cartilage, and in its course blends partly with fibres of the Interarytænoideus, which, as was described above, pass round the arytenoid cartilage without being attached to the same (figs. 4 and 4a).
- (c) The *lower* portion passes from the arytenoid cartilage downwards and forwards, and is inseparably fused with the so-called Crico-arytænoideus lateralis, which latter muscle has an entirely identical direction (fig. 9).

(a) Considering firstly the *horizontal* fibres, speaking generally, there is a marked tendency of the fibres which come from the outer lateral regions to course inwards, eventually lying parallel to the cords. In most cases the innermost fibres—those which arise from the processus vocalis—are directed

straight from behind forwards. The outer fibres, in order to be inserted over an area which is smaller and narrower than their place of origin, must necessarily assume an oblique course and converge forwards, and also decussate with the innermost straight fibres (fig. 8). This decussation of the inner and outer fibres may be seen over the whole area extending between the arytaenoid and thyroid cartilages, and, as before mentioned, the outer fibres tend to get inside the mesial ones. In some cases a fasciculus of fibres, arising just outside the processus vocalis, soon decussates with the fasciculus coming from the processus itself, and then forms the innermost horizontal band, or at least joins the fibres from the processus to form this band. This inner bundle is inserted at the so-called sesamoid cartilage, which, as mentioned in a former paper (25), and as Krause (19) has pointed out long ago, consists of dense fibrous tissue. This, again, is a typical tendinous insertion. The other fibres of this horizontal portion are inserted into the perichondrium of the thyroid cartilage.

Thus, as Disse (6 and 7) and Ruehlmann (16) have stated, the fibres are extremely interwoven. This decussation is best observed (*a*) near the arytaenoid cartilages, (*b*) more anteriorly near the insertion. Speaking very generally, as far as the middle or horizontal portion is concerned—(1) the fibres, coming from without and below, decussate with the inner and upper fibres, and the more external the origin of the fibres happens to be, the more anterior the place of decussation must be; (2) the fibres, the origin of which is more internal, show a distinct tendency to pass a little outwards; (3) there is no evidence of any insertion into the “chorda.” (In one case, where an infantile larynx was cut in numerical series and then stained with carmin, I succeeded in proving the existence of an epimysium between the muscle and the “chorda,” the fibrous tissue of the epimysium being stained intensely red, while the elastic tissue of the “chorda” hardly took the dye at all.)

(*b*) *The fibres which are directed downwards and forwards* form a mass with the Crico-arytaenoideus lateralis, extending between the arytaenoid, thyroid, and upper border of the cricoid cartilages. Sometimes an *intersectio tendina* partially separates the two muscles, but as Luschka (4) remarks, they have the

same direction and form an uninterrupted stratum. The relation of the Crico-arytænoideus lateralis to the Crico-thyreoideus is important. (i) A portion of the latter muscle arises, as Luschka (4) mentioned, from the inner surface of the thyroid cartilage, and here it comes in close relation with the Crico-arytænoideus lateralis, these two being at times separated only by a small interval containing vessels and nerves, at times, however, being quite inseparable. (ii) At their insertion, also, the two muscles blend. This, of course, only applies to the fibres of the Crico-thyreoideus which are directed downwards and forwards (the so-called Crico-thyreoideus anticus).

(c) The fibres of the Thyreo-arytænoideus running upwards and forwards are more complicated. Coming from behind, they pass along the outer side of the ventriculus. But as soon as the latter has risen properly above the level of the cord they diverge, so as to embrace the ventricle (figs. 4, 4a, 5, 6). Anteriorly they again join to reach the thyroid cartilage and the base of the epiglottis. The upper fibres are lost in the neighbourhood of the epiglottis, while the lower ones are inserted into the thyroid cartilage. These upper oblique bundles of the Thyreo-arytænoideus, as they surround the sacculus, are strengthened by fasciculi of the Interarytænoideus (see above). The uppermost fibres of the latter are found in the arytæno-epiglottidean folds in which they pass upwards and forwards. The most superficial ones end in the neighbourhood of the cartilage of Santorini, and are very short. The further down they are traced the longer they become. As long as they are in the arytæno-epiglottidean folds they do not reach the epiglottis. In the ventricular bands we find most of the fibres on the outer side of the sacculus. As the fibres which enclose the ventricle are directed upwards and forwards, it is naturally impossible in strictly horizontal sections to find a complete muscular ring around the sacculus. This is, however, well seen in oblique sections. Anteriorly these fibres end partly at the thyroid cartilage and partly near the base of the epiglottis. The "ventricular muscle" of Ruedinger (9) and Simanowsky (8) is, therefore, not a special muscle. I cannot agree with one of them (S.) in his statement "that this muscle has no connection whatever with the M. Thyreo-arytænoideus." This muscle is

indeed nothing but part of the whole muscular complex, and does not deserve a special name.

I have never seen fibres corresponding to Luschka's "Reflector" of the epiglottis (4), and am inclined to deny the existence of any such endolaryngeal muscle. But in some cases muscular fibres are found on the anterior surface of the epiglottis which come from the pharynx, and may well represent the function of a "Levator" or "Genio-epiglotticus" (Luschka). Again, occasionally a few fibres of the laryngo-pharyngeus (Henle) may be met with in the arytaeno-epiglottidean folds near the epiglottis. These, however, are of no interest. Connections between the pharyngeal and laryngeal muscles may at times be seen, the circular fibres of the pharynx communicating with the laryngeal sphincter. This recalls the foetal arrangement.

To sum up shortly: the Thyreo-arytaenoideus consists of (a) a horizontal middle portion, the fibres of which run straight from behind forwards, decussate and are interwoven in a marked manner; (b) an upper ascending portion, passing through the ventricular bands and the arytaeno-epiglottidean folds, and blending with the fibres of the Interarytaenoideus, enclosing the ventricle to end near the epiglottis or at the thyroid cartilage; (c) a descending lower portion which blends with the Crico-arytaenoideus lateralis, and comes into close connections with the Crico-thyreoideus.

(3) *Musculus Crico-arytaenoideus posticus.*

In young embryos (figs. 1, 2, 3), and up to the third month, the fibres of this muscle have the same direction as the Interarytaenoideus. Later, however, a "displacement" of its fibres takes place, so that its upper and innermost fibres preserve the same direction as the Interarytaenoideus, whilst the outer and lower ones (*i.e.*, the bulk of the muscle) pursue a more vertical course. This connection with and relation to the Interarytaenoideus is evidently of great importance with regard to some pathological and clinical questions (paralysis, &c.), and on this account it was deemed necessary to devote special attention to this muscle. From independent investigation I can indorse the statement I

find put forward by Dr Jelenffy (14), that "the uppermost fibres of the Crico-arytænoideus posticus *always* have so close a connection with the lowest fibres of the Interarytænoideus, that we might say they are fused (*verwachsen*).¹" The external vertical fibres of the Crico-arytænoideus posticus approach the processus muscularis in an arched manner (*im Bogen*) to be inserted there, or as Jelenffy has it, "*erst etwas abgerundet*," while the horizontal fibres approach the arytænoid cartilage in the manner of the Interarytænoideus. I, therefore, am at one with Jelenffy in considering "that part of the Crico-arytænoideus posticus which is attached to the lower region of the processus muscularis as the true abductor of the cord and the whole inner horizontal part as a phonatory muscle, equal in importance to all its fellows." It should be mentioned, that Fuerbringer (10) considers a closer connection between the Crico-arytænoideus and the Interarytænoideus to be of rare occurrence.

A few minute muscles, described separately by Luschka (4), are in all cases simply parts of larger muscles, and do not require special names. Thus the Ary-corniculatus obliquus of Luschka is only part of the Interarytænoideus, the Cricothyreoideus posticus, or Kerato-cricoideus, a branch of the Crico-arytænoideus posticus, the Dilator and Constrictor Vestibuli, and Thyreo-arytænoideus superior parts of the Thyreo-arytænoideus (*cf.* also Fuerbringer).

Conclusion.

This study of the laryngeal myology is also of special pathological interest, chiefly with regard to problems of nervous lesions. Physiologists and laryngologists are at variance with one another as to the true explanation of Rosenbach-Semon's law (29), which states "that in progressive organic lesions of the motor laryngeal nerves from the bulb downwards to the periphery, the abductors of the vocal cords always suffer primarily." Messrs Semon and Horsley (24) have lately done much to clear up the subject of the "motor nervous system of the larynx," extending a research which Professor H. Krause (26) had made peculiarly his own. The joint authors write:—

"The third question which results from the pathological facts ascertained by Rosenbach and Semon, viz., that in progressive organic

disease of the roots and trunks of the laryngeal nerves, first the clinical phenomena of isolated abductor paralysis are encountered, and that *post mortem* the abductor muscles are found to have degenerated more than the adductors or even exclusively, is naturally this: Are there notable differences between the nerve fibres supplying these antagonistic groups of muscles, or are these differences to be found in the biological constitution of the muscles themselves?"

In this spirit, a careful study of the muscles of the larynx seems to be of importance. The following points in connection with the biological constitution of the muscles and the myology of the larynx are noteworthy:—

- (1) The preponderance of sphincter-fibres over dilator-fibres.
- (2) Taking the muscles as special and individual muscles, as it is generally done, there is no muscle containing exclusively dilator-fibres.
- (3) The Crico-arytænoideus posticus acting with the Crico-arytænoideus lateralis, &c., must cause an approximation of the cords, *i.e.*, act as sphincter.
- (4) The close connection between the Crico-thyreoideus (anticus) and the mass of the Thyreo-arytænoideus and Crico-arytænoideus lateralis [*cf.* R. Wagner (30)].

Further questions, as, *e.g.*, the possibility of a motor and inhibitory nervous mechanism, must be left for a future time. The purpose of this sketch was a simplification of the myology of the larynx, founded on anatomical observations made on organs removed from human embryos and individuals of all ages. I hope, at a future time, to add the results of comparative anatomical studies.

For the drawings, I am indebted to Robert Schwann, Esq. (Berlin). My thanks are due chiefly to Professor Virchow for his generosity in placing his laboratory at my disposal, and for its unrivalled supply of material. I have also to thank Mr Bowlby of St Bartholomew's Hospital for some valuable material.

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EXPLANATION OF PLATES VI., VII.

In all the drawings the same abbreviations have been used. Thus—

- Th. c = Thyroid cartilage.
- C. c = Cricoid cartilage.
- A. c = Arytænoid cartilage.
- I. c = Inferior cornu of thyroid cartilage.
- h = Hyoid bone.
- L = Lumen of larynx.
- Ph = Pharynx.
- S. p = Sinus pyriformis.
- P. s = Pars respiratoria.
- P' s' = Post-arytænoid sinus.
- 1 = pharyngeal muscles.
- 2 = M. Interarytænoideus.
- 3 = M. Thyreo-arytænoideus.

Figs. 1-3.—*Horizontal sections through the larynx of an early embryo.*

Fig. 1 shows posteriorly the circular pharyngeal muscles. On the right these fibres arch around the inferior cornu of the thyroid cartilage to blend with the laryngeal muscles. This specimen shows clearly the sphincter-like arrangement of the intrinsic laryngeal muscles, the M. Thyreo-arytænoideus being directly continuous with the M. Interarytænoideus.

Fig. 2 represents a horizontal section through the larynx of the same embryo, at a lower level. It shows pretty much the same as the previous figure, with this exception, that the M. Interarytænoideus has been replaced by the M. Crico-arytænoideus posticus (2').

Fig. 3. A horizontal section at a still lower level.

3' = Mass of the M. Thyreo-arytænoideus and M. Crico-arytænoideus lateralis. This is seen to be continuous with the M. Crico-arytænoideus posticus (2').

Figs. 1a and 2a.—*Horizontal sections through the larynx of a four-months foetus.*

Fig. 1a shows distinctly the continuity between the fibres of the M. Thyreo-arytænoideus and the M. Interarytænoideus.

Fig. 2a. Through the true vocal cord. Shows the same as fig. 1a. v. c. = vocal cord.

Fig. 3a.—*An obliquely coronal section through the larynx of a foetus (3-4 months).*

The drawing shows how the M. Thyreo-arytænoideus (3) sends fibres around the ventricle (V) into the ventricular band (v. b.), to form the "ventricular muscle" of Ruedinger.

Figs. 4-9.—*Horizontal sections through the larynxes of newborn children.*

Fig. 4. The ventral fibres of the M. Interarytænoideus (2) stretch across without decussation, while the dorsal fibres decussate. On the left side this muscle sends off fibres to join the M. Thyreo-arytænoideus (3), which at this level is found entirely on the lateral aspect of the ventricle (V).

Fig. 4a. At level of the "aditus ad ventriculum laryngis." The M. Interarytænoideus (2) sends large bundles forwards towards the ventricle.

Fig. 5. At a higher level than either 4 or 4a. The dorsal or superficial fibres of the M. Interarytænoideus (2) arching around the

arytænoid cartilage (A. c.) pass towards, and around, the ventricle (V). On the left side they are strengthened by bundles of the M. Thyreo-arytænoides.

Fig. 6. A similar section.

Fig. 7. A section through the vocal cords (v. c.). Behind the decussation of the M. Interarytænoides (2) is well seen. The dorsal fibres of this muscle arch around the arytænoid cartilage (A. c.) to join the M. Thyreo-arytænoides (3).

Fig. 8. This drawing should be studied with a magnifying glass. It shows well the decussation of the fibres of the M. Thyreo-arytænoides (3), and their relation to the elastic tissue of the vocal cord (v. c.).

Fig. 9. Section through the crico-arytænoid articulation. This specimen demonstrates well the close connection between the fibres of the M. Thyreo-arytænoides (3) and the M. Crico-arytænoides lateralis (3'). Behind is the M. Crico-arytænoides posticus (4).

A NOTE ON IDENTICAL MALFORMATIONS IN TWINS. By BERTRAM C. A. WINDLE, M.A., M.D., D.Sc.,
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THE twins, whose condition forms the subject of this communication, were sent to me by my friend Dr Evers, who informs me that they were contained in the same membranes. The description of one will suffice, with a few slight alterations, for both. There was a deficiency of the anterior wall of the abdomen, the intestines and part of the liver being contained in a thin membranous sac, which extended from the umbilicus to the pubes. From between the thighs, posteriorly, there hung a sac the size of a small walnut, which sprang from the posterior part of the vertebral column, extending upwards to about the centre of the sacrum. On the inner aspect of either thigh there was a small fold of skin, apparently representing the labia majora; but with this exception there was no appearance of external genitalia, save that in the middle line there was a small opening. There was no anal orifice. On dissection it became evident that there was a wide separation of the pubes of either side. The median orifice already alluded to, led into a small sac which represented either the bladder or a cloaca, probably the latter, though, partly on account of the matting together of the viscera, due to the spirit in which the specimens had been lying for some time prior to examination, I was unable to trace any opening of the intestine into this sac, nor was I able to find the termination of the intestine elsewhere. On opening the sacral sac its fluid contents escaped, and it was then seen to be lined with what appeared to be a mucous membrane, very similar to that of the bladder in naked-eye appearance; in fact, the resemblance to the interior of that viscus was very marked, being increased by the (?) muscular strands which ran in various directions through its wall. On the anterior wall of the sac were two openings, the upper and larger of which led directly into the theca of the spinal cord. The lower

and smaller opening was situated immediately below the lower end of the vertebral column, and was blind. The wall at its lower end was extremely thin, and, on examining it with a probe, it became evident that it was formed by the posterior wall of the bladder or cloaca, the membrane, in fact, being a kind of party-wall between the two sacs. The two fetuses, as I have already stated, were in every respect identical, save that in one the urethral or cloacal orifice and the blind pouch at the lower part of the sacral sac were somewhat larger than in the other, rendering the examination of the parts easier.

Before passing to the general question of similar malformations in twins, it will be well to consider the nature of those presented by the specimens in question. We have to do with a sacral sac continuous above with the theca of the spinal cord, a sacral meningocele, which below the end of the vertebral column was almost continuous by a narrow passage with the cloaca. This condition seems to me to be best explained by the supposition that there has been a partial persistence of the neurenteric canal, together with the formation of a sac by the dilating influence of the rachidian fluid. The possibility of such a dilatation of this passage has been alluded to by Bland Sutton (1). I have looked through Braune's well-known work (2), but have failed to note therein any case quite corresponding to that just described.

Turning now to the subject of similar or identical malformations in twins, it may first be noted that in twins one may be affected with a congenital malformation which the other does not share, a point which is used by Vrolik (3) as an argument against the theory of maternal impressions. "In the case of twins," he says, "as the acephali specially show, one child may be malformed and the other in perfect condition, notwithstanding they were both exposed to the same influences." In connection with this remark, however, it must be noted that it is highly probable, if Cleland's hypothesis as to their nature be accepted, that the acephali are not cases in point, and that if we also remove from consideration those instances where, as in the foetus papyracei, the malformations of one twin are mechanically produced by the other, the number of instances where one twin is normal and the other malformed will be very

greatly reduced. Cases where both twins are affected with identical malformations do occur, according to Ahlfeld (4), "nicht selten." I am somewhat in doubt whether they occur, however, with the frequency which this remark would lead us to believe.

In the Rotunda Hospital, Dublin, during the seven years intervening between 1847 and 1854 there were delivered 13,748 women, of whom 233 had twins, or about 1 in 59 (5). Amongst these cases of twins there was not a single one in which the two children presented similar malformations.

I have looked through a number of text-books and papers, and will now briefly detail the cases which I have met with:—

1. Naegele (6). Twins with arrested development of the external genitalia, so that both were considered to be female until their seventeenth year. (Hypospadias.)
2. Katzky (7). A similar condition of hypospadias.
3. Van Mons O. Max (8). Twins with hermaphroditismus masculinus.
4. Lehmann (9). Twins with occipital meningoceles of the same size, both also affected with hypospadias.
5. D'Outrepont (10). Twins with similar condition of spina bifida.
6. Walters (11). Twins with occipital meningocele and arrested development of the upper and lower extremities, both of which were only one-fourth of their normal length. (Considered to be a case of phocomelia by Gerl.)
7. Otto (12). Twin anencephali, whose palates, though not fissured, were both marked by a deep longitudinal furrow. (It is interesting to note that this is the only case of twins affected with similar malformations described in this work.)
8. Ahlfeld (13). Male twins both affected with right-sided congenital hydrocele.
9. Ellis (14). Twins, each affected with cyclopia.
10. Curling (15). Twins, the sex of whom was doubtful at birth, both being christened as boys. A post-mortem examination, however, revealed the fact

that they were girls, each with an abnormally developed clitoris.

11. Siebold (16). Twins, possessing six fingers on each hand and six toes on each foot. They lay in the same amniotic cavity.
12. Delbaere (17). Twins, each possessing a supernumerary pollex on the right side.
13. Molina (18). One twin had six fingers, and the other six fingers on each hand and six toes on each foot.
14. Nicolas (19). Twins, each possessing a sternalis muscle. (The muscle was hereditary, the mother also having one.)
15. Nebensohn (20). Twins with a remarkable conformation of the left parietal bone. (I have not been able to refer to the original paper to ascertain the nature of this malformation.)
16. Galton (21). "Three pairs of twins have peculiarities in their fingers; in one case it consists in a slight congenital flexure of one of the joints of the little finger; it was inherited from a grandmother, but neither parents nor brothers nor sisters show the least trace of it. In another case the twins have a peculiar way of bending the fingers, and there was a faint tendency to the same peculiarity in the mother, but in her alone of all the family. In a third case, about which I made a few inquiries, which is given by Mr Darwin, but is not included in my returns, there was no known family tendency to the peculiarity in the twins of a crooked little finger."

The cases cited above, with that which I have myself described, are good examples in one direction of the similarity which, in different ways, exists between homologous twins,—a similarity explained by their origination by the fission of a single ovum. It will be observed that instances occur of the two great classes of malformations by defect and by excess. In the former case it might perhaps be argued that the arrest of development common to the two was the result of a common

cause in the maternal organisation, or in the placental circulation, though even then there must be a remarkable similarity in the embryos to respond in an identical manner to the same stimulus. But this argument cannot be applied in cases of superfluity of development, such as polydactyly, or hypertrophy of the clitoris. But both the one class and the other are, to my mind, better explained by the theory that the twins, proceeding from a common ovum, were possessed of an identical plasma containing inherently the tendency to the malformation which subsequently developed.

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- (14) *Trans. Obst. Soc.*, vii., p. 160.
- (15) *Med. Times and Gazette*, 1852, p. 84.
- (16) *Neue. Zts. f. Geburtsk.*, Bd. 13, s. 243. (Ahlfeld.)
- (17) *Spec. de polydactylo congen. in gemellis*, *Lugd. Bat.*, 1847. (Ahlfeld.)
- (18) *El Siglo Medico*, 1855, p. 187. (Quoted by Fackenheim, "Hereditärer Polydaktylie, u. s. w.," *Jen. Zts. f. Wissensch.*, xxii. 352.)
- (19) *Soc. biol. Paris*, 29th November 1890. *Rev. Int. de Bibliog. Med.*, January 1890.
- (20) *Inaug. Dissert. Tübingen*, 1857. (Ahlfeld.)
- (21) *Jour. Anthropol. Inst.*, vol. v. p. 391.

ON THE CAUSE OF THE TWISTING OF THE UMBILICAL CORD, ILLUSTRATED BY MECHANICAL MODELS. By F. J. ALLEN, M.A., M.B. Cantab., *Professor of Physiology in Mason College, Birmingham.*

THE umbilical cord of the human foetus becomes twisted upon itself within the early weeks of gestation. The number of revolutions is variable, and accurate information as to the maximum and minimum numbers is not easily accessible. The twisting consists essentially of the winding of the two umbilical arteries around the single vein, the surface of the cord probably moving with the arteries as they turn. The direction may be that of either a right or a left handed screw. Possibly cases may be found in which the two directions alternate, but this condition is not recorded by any authority that I have read. The twisting does not occur in all mammalia. Preyer sought it in vain in several multiparous animals. In order that it may occur, the foetus must be freely suspended in the amniotic cavity, so as to revolve with the cord without obstruction through contact of amnion itself. The revolution begins very early. Preyer found it begun already in a human embryo one inch long, and very complete in an embryo of eight weeks.

No satisfactory explanation of the cause has been given, unless that which I offer can be accepted.¹ Preyer and others attributed the twisting to the movements of the embryo; but such an explanation is hardly tenable, for it supposes that the embryo keeps up a constant movement of such a peculiar kind as to keep itself revolving on the axis of its own umbilical cord; and what form of movement could bring this about it is most difficult to conceive. For my part I prefer to look for some physical property in the cord itself, which may bring about the twisting independently (or nearly so) of foetal movements.

My own explanation was put forward six or seven years ago,

¹ See Addendum at end.

incidentally, in an article in *Nature* (July 23, 1885, p. 268). In that article I used the following words:—"The twisting may be due to the excessive growth of the umbilical arteries, so that they are obliged to take a tortuous course; and when a slight obliquity has been once established, every pulsation will tend to increase the spiral, and every movement of the foetus or the mother will be taken advantage of; the cord and the foetus revolving together until, with the growth of the foetus, the friction of the amnion puts an end to the rotation."

It had from the first appeared to me possible to demonstrate this action by means of a working model. But every model that I could mentally devise seemed to present some impracticable feature. For instance, an ideal model would contain two elastic tubes, in imitation of the umbilical arteries, which could be lengthened at will by forcing water into them; and they should be fixed in some manner which would allow them to twist spirally around each other during their lengthening. But practically a tube, even of the most elastic rubber, can only be lengthened a very little by distension. After many devices it occurred to me that the mechanical effect would be just the same if, instead of the tubes lengthening, the rest of the cord became shorter. Applying this principle, and imitating the various conditions of relative mobility of parts in the umbilical cord, I at last constructed the model of which photographs are here given. (Figs. 1 and 2.)

The model consists of (1) two india-rubber tubes, representing the umbilical arteries, united by (2) several cross-bars of wood representing the support and restraint offered by the tissues of the cord, and (3) an india-rubber cord, one-third shorter than the tubes, threaded through the cross-bars, and representing the tendency of the general tissues of the cord to grow less in a longitudinal direction than the arteries. The cross-bars are joined to the tubes by means of a thin wire which projects from each end of each bar, passes transversely through the tube, and is bent into a loop. This arrangement allows the rubber and cross-bar to move freely, one on the other, in any position of the apparatus. The india-rubber cord is threaded through the centre of each cross-bar by a hole, which must be small enough to grip the cord tightly and prevent slipping. The cord is

retained by a knot at each end of the model. To the middle of each terminal cross-bar is tied a piece of string, by pulling on which the apparatus can be stretched. When demonstrating the action of the model, it is important to hold it only by these

Fig. 1.

Fig. 2.

Fig. 3.

strings. If any other part be held in the hand it will be prevented from making its natural movement.¹

It will be seen that the model represents an umbilical cord whose arteries have grown in excess of its other tissues. Such

¹ The dimensions of my model are :—Length of tubes, 36 ins. ; thickness, $\frac{1}{8}$ in. ; length of elastic cord, 24 ins., slightly shortened by the knot at each end ; thickness, $\frac{1}{16}$ in. ; length of cross-bars, $4\frac{1}{2}$ ins. ; cross-bars attached to the tubes at intervals of 3 ins.

an apparatus, when stretched longitudinally, has the appearance shown in fig. 1 ; but as soon as it is released from the stretching force, it falls into the twisted position shown in fig. 2, which is, in fact, its position of equilibrium. The energy with which the twisting occurs is such as to suggest that the umbilical cord, if it twist from a similar cause, may readily turn the foetus round with itself so long as the foetus is small enough, and the amniotic cavity roomy enough, to allow unimpeded movement.

Various modifications of this model are possible, of which a simple one is that represented in fig. 3. It is made thus:—An india-rubber tube and a cord of the same material, both of the same length (say 3 ft.), are enclosed in hems along the margins of a strip of muslin, so that the clear space between them is 2 ins. wide. The rubber cord is then taken by its ends and stretched to one and a half times its original length, whereby it will, of course, be partially drawn out of its hem at each end. It is then released, and its contraction brings the apparatus to the form shown in fig. 3. This model demonstrates the principle fairly well, but its behaviour is less striking than that of the former one.

It is not easy to imagine what advantage can accrue to the foetus or to the mother as a result of the twisting. It is usually supposed to prevent obstruction of the circulation in case of the cord becoming pressed. But the effect would rather be to increase obstruction, for, in the case of a flat cord (as in most mammalia), pressure can only tend to cause the arteries to take up a position parallel to the vein; the firmer arteries will then ward off pressure from the more flaccid vein. On the other hand, when the arteries are spiral, pressure will cause the vein to be nipped by the arteries as with a tourniquet, because the arteries lie across the course of the vein.

Again, it may be suggested that the spiral arteries tend to prevent the vein from kinking when the cord gets sharply bent. Here, too, the argument is not entirely valid; for in a flat cord the vein would hardly kink until the pressure were sufficient to kink the cord as a whole, *arteries included*. Now, spiral arteries are more in danger of kinking than straight ones, since pressure applied to any part of the cord might kink one of the curves. There is, however, one advantage, though it be but a compara-

tive one, namely, that in a flat cord the kinking pressure would be exerted on a single (accidental) bend in the arteries, whereas in a twisted cord the pressure would tend to be distributed over several coils of the arteries.

ADDENDUM.—Since the foregoing was written, Sir William Turner has drawn my attention to a paper by the late Dr John Simpson in the *Edinburgh Medical Journal*, vol. v. (1859-60), page 22, in which the writer puts forward a theory similar to my own. He attributes, however, the whole phenomenon to the impulse given to the vessels by the beats of the heart. This is the explanation which first occurred to me some years ago, but afterwards I thought it insufficient, and considered that the twisting was due primarily to the overgrowth of the arteries, and that the pulse acted as an accessory.

Dr Simpson ingeniously explains the prevalence of the left to right (or reversed corkscrew) spiral, by the observation that (1) the right hypogastric artery is the larger of the two, and is at its origin more directly in the line of the aortic trunk; (2) the arteries usually pass through the umbilicus on the anterior side of the vein, and thus the stronger pulsation in the right artery should cause it to curve more than the left, and so start the reversed corkscrew twist. This explanation applies equally well whether the agent be arterial distension or overgrowth. Dr Simpson quotes instances of alternating spiral, also of absence of twist. In the latter condition the arteries had nevertheless grown too long, and were "usually seen to fold back on themselves, as if to dispose of their greater length than [that of] the vein."

**ABNORMAL ARRANGEMENT OF ARTERIES IN THE
REGION OF THE KIDNEY AND SUPRA-RENAL
BODY.** By ALFRED W. HUGHES, M.B., F.R.C.S. (Eng.
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THE relations which are normally and abnormally found to exist in the vascular arrangements of the kidneys, supra-renal bodies, and testes are necessarily of great interest, as these organs originally appear in close proximity to one another in the immediate neighbourhood of the primitive aortæ.

In the normal condition the supra-renal bodies receive branches from the renal arteries, and it is not unusual to find one of the spermatic arteries arising from the same source; and again, on the left side the renal vein normally receives the supra-renal and spermatic or ovarian veins.

I have recently examined a male subject presenting a very remarkable arterial arrangement in the lumbar and iliac regions.

On the *left* side of this subject the supra-renal body received several branches from the phrenic artery and aorta as usual, and at its lower extremity received branches from an *abnormal artery* (4) which originated in the upper angle formed by the aorta and left renal artery. These branches apparently represented the normal inferior capsular. This "abnormal artery" was rather larger than an ordinary spermatic, and having supplied branches to the supra-renal body, insinuated itself between that organ and the kidney. Having thus reached the anterior surface of the kidney, it divided into two fine branches, the *outer* of which passed along the convex outer border of the kidney, terminating in the extra-peritoneal fat, a little distance below the iliac crest.

The *inner* branch, which was rather larger than the outer passed almost vertically downwards on the surface of the kidney, and having reached the iliac fossa, was joined there by a branch of the spermatic artery, thence passing into the inguinal canal along with the normal spermatic artery. (The inguinal canal,

having been already dissected, I regret I was unable to trace the artery to its destination.) Further, from the left spermatic artery, about one inch from its origin, a branch (5) was given off which almost immediately divided into two fine twigs (ascending and descending). The *ascending* branch passed upwards in front of the renal vessels, and joined the trunk of the "abnormal artery" close to the supra-renal body, and from the anastomotic

loop thus formed branches were supplied to the capsule of the kidney, ureter, and peri-renal fatty tissue. The *descending* branch passed into the iliac fossa, where it joined the internal branch of the "abnormal artery," as previously mentioned.

Assuming that the branch which passed into the inguinal canal reached the testis, we have here exemplified the close developmental connection of the three organs—supra-renal body, kidney, and testis—by an originally close plexus becoming converted into a wide-meshed one by the subsequent descent of the testis.

On the *right* side the arrangement was somewhat different. Springing from the renal artery, close to its root, was a large branch (6) which entered the substance of the kidney on its anterior surface near its upper extremity. From this branch numerous twigs were supplied to the supra-renal capsule, from one of which a long branch was given off, which passed down in front of the renal vessels to reach the outer side of the spermatic artery opposite the bifurcation of the aorta. Whether this branch reached the inguinal canal I am unable to say, from the advanced stage of the dissection in this region.

Sir William Turner, in his article on the "Sub-peritoneal Arterial Plexus,"¹ has referred to a number of branches given off from the renal and spermatic arteries in the lumbar and iliac regions which join that plexus. There is little doubt, from the similarity in their distribution, but that the fine branches which I have described as entering the peri-renal and other parts of the extra-peritoneal fat communicated with the sub-peritoneal arterial plexus; but the inosculations being small, excluded the possibility of demonstration in the absence of special injection.

As this anomalous distribution was so marked, and differed from any case I have been able to find on record, I have ventured to consider it worthy of special notice.

REFERENCES TO DIAGRAM.

1. Renal arteries.
2. Spermatic arteries.
3. Inferior phrenic artery (left).
4. Abnormal artery (left side).
5. Abnormal branch of left spermatic artery.
6. Abnormal artery (right side).

¹ *British and Foreign Medico-Chirurgical Review*, 1863.

THE NUTRITIVE IMPORTANCE OF THE YOLK SAC.

By ARTHUR ROBINSON, M.D., *Senior Demonstrator of Anatomy at the Owens College, Manchester.* (PLATE VIII.)

BALFOUR'S statement that "the most fundamental change which has taken place in all the existing placentalia is the exclusion of the umbilical vesicle from any important function in the nutrition of the foetus,"¹ has not been substantiated by Hubrecht's observations upon the development of the insectivora,² which have shown, on the contrary, that in the hedgehog at least, the yolk sac plays an important part as a nutritive organ in the early stages of development.

The importance of the yolk sac as a nutritive agent is not a peculiarity limited to the insectivora, for the organ plays a no less important part in the opossum³ and other marsupials,⁴ and the observations I now record show that in some of the rodents it is the only organ of nutrition during a certain period of development, and that it remains functionally important during the greater part, if not the whole, of foetal life.

The rodents in which this has been observed are the mouse (*Mus musculus*) and the rat (*Mus decumanus*).

The early stages of the development of these animals have already been fully described,⁵ and it is sufficient now to state that at the commencement of the seventh day of development, the ovum of the mouse consists of a large yolk sac (YS, fig. 1), upon the upper pole of which rests a comparatively small mass of primitive epiblast.

¹ *A Treatise on Comparative Embryology*, vol. ii. p. 218, London, 1881.

² "The Placentation of *Erinaceus Europæus*, with Remarks on the Phylogeny of the Placenta," *Quart. Journ. of Micr. Sc.*, new series, vol. xxx., part iii., pp. 283-404, Dec. 1889.

³ E. Selenka, *Studien über Entwicklungsgeschichte der Thiere, Das Opossum*, Wiesbaden, 1886.

⁴ R. Owen, *Comparative Anatomy and Physiology of Vertebrates*, vol. iii. pp. 718-723, London, 1868.

⁵ A. Robinson, *The Development of Two Rodents*. A Thesis for the Degree of M.D., presented to the University of Edinburgh in April 1890, for which the Medical Faculty awarded a Gold Medal.

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The cavity of the yolk sac lies within the primitive hypoblast, and it is traversed by protoplasmic strands, which unite different portions of its wall together, and which indicate its development by the vacuolation of a syncytium.

The primitive epiblast is separable into two parts, a superficial and a deep; the latter is a rounded mass, which rests upon and partially invaginates the upper pole of the yolk sac; from it the epiblastic portion of the embryo and the amnion are formed, and it is therefore the epiblast proper, or the formative epiblast (E, fig. 1). The former is a thin layer which covers the formative epiblast, and, extending beyond the latter, rests by its margin upon the wall of the yolk sac; it eventually becomes the epiblastic portion of the foetal placenta, and is therefore the "trophoblast" (T).

The ovum thus constituted lies free within a crypt which has been formed, on the antimesometrial or distal side of the uterine cavity, by the proliferation of the subepithelial tissues, within a definitely limited area, and the consequent upheaval of a circular fold of decidual tissue.

The cavity of the crypt is narrow, and its walls, which are thick and vascular, gradually rise until they fuse with the mesometrial or proximal wall of the uterus, in which proliferation of the subepithelial tissues has also occurred.

The circular fold of decidua commences on the distal walls of the uterus at the sixth day, and it fuses with the proximal portion of the decidua at the eighth day, when the crypt is converted into an enclosed space of oval form.

At first the crypt is lined by a distinct cubical epithelium, but at the seventh day this has disappeared in the situation occupied by the ovum, which consequently lies in direct contact with the subepithelial mucosa.

The ovum is placed in the crypt so that its epiblastic pole is mesometrial or proximal, and its hypoblastic pole anti-mesometrial or distal. The interpolar area, which at first is constituted entirely by hypoblast, is in direct contact with the wall of the crypt, to which it becomes closely united, and thus when the crypt becomes converted into a closed space, it is divided by the enclosed ovum into two parts, a proximal and a distal. The former is the larger, and it is bounded distally by the epiblastic

pole of the ovum. The latter is the smaller, and it is bounded proximally by the hypoblast of the ovum. Both the proximal and distal portions of the space eventually become converted into blood sinuses, which are filled with maternal blood.

During the seventh day the formative epiblast increases and assumes a more distinctly oval form. Its distal extremity projects against the proximal end of the yolk sac, which it partially invaginates, and thus the hypoblast can be divided into two parts, the internal or invaginated (IHY), and the external or non-invaginated (EHY, fig. 2, Plate VIII). The former is a comparatively thick layer, which lies in contact at first with only a portion of the periphery of the formative epiblast. The latter is a thin layer, which is slightly overlapped proximally by the margin of the trophoblast, but in the greater part of its extent lies in direct contact with the subepithelial uterine mucosa.

The condition represented in fig. 2 is very transitory, for the trophoblast rapidly proliferates, growing both towards the yolk sac and towards the mesometrial wall of the uterus. As it grows towards the yolk sac it pushes the formative epiblast before it, and completes the invagination of the yolk sac (fig. 3, Plate VIII).

Towards the end of the seventh day (fig. 3), as a result of the changes above recorded, the formative epiblast is an oval mass which is surrounded by the invaginated hypoblast, except proximally where it lies in contact with the trophoblast. The trophoblast is separable into two parts. One of these, the distal part (DT), is enclosed by the invaginated hypoblast; the other, the proximal part (PT), is in direct contact with the subepithelial mucosa, to which it is closely united, whilst its flange-like margin overlaps the folded margin of the yolk sac. The invaginated hypoblast is also divisible into two portions: one lies in contact with the formative epiblast, and takes part in the formation of the embryo; it is, therefore, the embryonic hypoblast (EMY): the other surrounds the distal trophoblast, and constitutes a part of the extra-embryonic hypoblast, which is completed by the uninvaginated hypoblast.

It is noteworthy also that at this period, the end of the seventh day, numerous slit-like blood spaces appear in the uterine mucosa, and that many of these spaces are separated

from the proximal trophoblast and the external hypoblast only by a very thin wall of maternal tissue.

In the early part of the eighth day a cavity, the future amniotic cavity (AMC), is present in the formative epiblast. During the eighth day all parts of the ovum grow rapidly, and at its close the cavity of the formative epiblast has been extended into the distal trophoblast in the case of the mouse, whilst in the case of the rat a cavity (TC) which develops separately in the distal trophoblast has united with the epiblastic cavity.

The proximal portion of the trophoblast is much larger, and in its interior numerous spaces are present. These spaces are evidently in communication with the blood spaces in the decidua, for they are filled with maternal blood. The slit-like decidual spaces in the immediate vicinity of the ovum fuse together into a large sinus, and simultaneously with their fusion their inner walls disappear. By these processes a blood sinus is formed, bounded externally by maternal decidua, and internally by the external hypoblast and the trophoblast. The proximal and distal portions of the ovular chamber also become converted into blood spaces, and thus at the end of the eighth day the outer surface of the proximal trophoblast and the outer surface of the external hypoblast are bathed by maternal blood, which has also penetrated into spaces which have developed within the trophoblast.

Between the cavity of the yolk sac and the maternal blood, at the end of the eighth day, there is only a thin membrane formed by a single layer of flattened hypoblastic cells (EHY, fig. 4). Through this osmosis may readily take place, and thus pabulum would be transmitted to the embryonic area which, on account of its position, is separated from any other source of nutrition.

Under these circumstances the outer surface of the yolk sac may be looked upon as a nutritive area, and its importance in this respect is emphasised by subsequent events.

At the commencement of the ninth day a mass of mesoblast projects backwards from the posterior end of the embryonic area, and then rapidly extends round the sides of the cylindrical ovum between the epiblast and hypoblast to the anterior end of the area. In the posterior part of this extra-embryonic

mesoblast two slit-like coelomic spaces appear. By the growth of the mesoblast, and by the fusion and extension of coelomic spaces, the trophoblast is separated from the epiblast, and the amnion is formed (figs. 5 and 6).

As the extra-embryonic coelom extends, the distal portion of the trophoblast gradually recedes from the epiblast; in other words, it is pushed out of the invagination cavity by the extension of the coelom, and the hypoblast, with which it lay in contact, is gradually covered by a layer of splanchnic mesoblast. At the same time the cavity of the trophoblast is obliterated, and its distal and proximal walls are fused (fig. 6).

Towards the end of the ninth day the allantois grows out from the posterior end of the embryonic area into the extra-embryonic coelom (fig. 7). It is at first a solid mass of mesoblast, afterwards numerous vessels are developed within it, but *it never contains a diverticulum from the alimentary canal*. The solid mesoblastic allantois hangs free in the extra-embryonic coelom until the eleventh day, when it fuses with the somatic mesoblast which covers the distal portion of the trophoblast (fig. 8).

After this fusion has occurred vascular mesoblastic villi are projected into the trophoblast, which is thus divided into a series of irregular columns (fig. 8). In the interior of these columns are numerous anastomosing spaces containing maternal blood. As the ramifications of the foetal mesoblastic villi become more numerous and extensive the trophoblastic septa which separate them from the maternal blood are gradually reduced in thickness, and at the fourteenth day only a thin layer of trophoblast and the endothelial walls of the foetal vessels intervene between foetal and maternal bloods.

When the allantoic villi have penetrated the trophoblast, and thus the foetal vessels have been brought into close relation with maternal blood, there are two sources from which the embryo may obtain pabulum—through the allantoic placenta and through the yolk sac walls. At this period the cephalic and caudal curvatures have appeared, and the embryonic hypoblast is enclosed within the embryo (fig. 9); but as there is a communication between the gut and the remainder of the cavity of the vitelline sac it is still possible that the embryonic hypoblast

may absorb nutriment which has diffused from the maternal blood through the thin outer wall of the yolk sac into its cavity. There is, however, another way in which pabulum may be withdrawn from the yolk sac and conveyed to the embryo. During the formation of the coelom the greater portion of the invaginated wall of the vitelline sac becomes covered by a layer of splanchnopleure mesoblast (S.P.M., figs. 5, 6, 7, 8). In this mesoblast, in the extra-embryonic area, numerous blood-vessels are rapidly formed, and as soon as the vitelline circulation is established, nutriment absorbed from the cavity of the yolk sac by the hypoblastic cells of its invaginated wall may be taken up by the vitelline vessels, which lie in contact with the hypoblast cells, and carried to the foetus. In connection with this point, it is interesting to note that over a large portion of the extra-embryonic area the wall of the yolk sac becomes villous (fig. 9), and the hypoblast cells covering the villi, assuming a columnar character, closely resemble the epithelial covering of the adult intestinal villi.

As the allantoic placenta is completed, and as its circulation is established, the folds of the decidua reflexa are gradually separated from the distal wall of the uterus. The separation is completed about the sixteenth day, when the continuity of the uterine canal is re-established, and the embryo, suspended by its placenta and enclosed within the folds of the decidua reflexa, is henceforth attached only to the proximal (mesometrial) side of the uterine canal.

Whilst the folds of the decidua reflexa are being separated from the distal wall of the uterus they also become thinner, and the circulation within them is first reduced, and then ceases as the blood-channels are obliterated, the reflexa and the outer wall of the sac being at the same time transformed to a thin membrane which intervenes between the uterine cavity and the cavity of the vitelline sac (EHY, fig. 10).

There can be no doubt that as the circulation in the decidua reflexa ceases the importance of the outer wall of the yolk sac as a nutritive area also diminishes, but the cavity of the sac remains, and the villi on its inner wall become larger and more numerous, facts which may be taken as indicative of their continued function.

During the period of reduction of the decidua reflexa there occurs one of the most suggestive events in the development of the vitelline sac, in so far as its nutritive importance is concerned.

At the eleventh day, immediately after the allantois has fused with the somatic mesoblast on the distal surface of the trophoblast, the margin of the yolk sac, ENS, which has been termed by Duval¹ the entodermal sinus, lies immediately internal to the margin of the trophoblast (fig. 8).

At the fourteenth day, as the result of the rapid growth of the peripheral portion of the trophoblast, and the external hypoblast in relation to it, the entodermal sinus is situated beneath the central part of the trophoblast, ENS, fig. 9, into which it projects. The entodermal sinus is circular, and it forms the boundary of a depression on the under surface of the trophoblast, which is filled by the foetal mesoblast. This depression is the hilum of the placenta. Its diameter, 1.024 mm., is one-third of the diameter of the foetal placenta.

It is at this period also, whilst the circulation in the decidua reflexa still continues, that the internal hypoblast becomes villous over about half its extent. Each villus consists of a core of splanchnic mesoblast, surrounded by a layer of cubical or columnar hypoblast cells.

In sections of the foetal placenta at the sixteenth day (Plate VIII. fig. 10), numerous spaces, lined with cubical epithelium, are seen in the hilum, along the line of fusion of the mesoblast and trophoblast. When they are traced through a series of sections they are found to be continuous with the entodermal sinus. Duval² has suggested that the sinus is festooned, and that the spaces are merely portions of the irregular sinus, cut in sections, which have not passed directly through the middle of the hilum of the placenta. In support of this explanation, he points out that the epithelium of the entodermal sinus is cubical on the side next the mesoblast, but somewhat flattened on the outer wall of the sinus against the trophoblast, and that one wall of

¹ "Le Placenta des Rongeurs, troisième part, Le Placenta de la Souris et du Rat," *Journal de l'Anatomie et de la Physiologie*, p. 387, année 1891, No. 4, Juillet-Aout.

² *Ibid.*, p. 388.

each space is lined by cubical epithelium, and the other by a layer of flattened cells. If the spaces were only found in sections which passed through the margin of the hilum, Duval's explanation might be accepted as satisfactory; but as they are present in all sections which pass through the hilum, and as they anastomose with each other in the hilum, they are something more than mere sections of the festooned margin of the entodermal sinus. In reality, they are portions of diverticula from the sinus which have penetrated the hilum and anastomosed with each other in its interior.

The significance of this peculiarity is emphasised by the fact that the diverticula penetrate the hilum simultaneously with the cessation of the circulation in the decidua reflexa,—that is, simultaneously with the cessation of the endosmosis from the maternal blood into the yolk sac; for at the sixteenth day the decidua reflexa and the external hypoblast are reduced to a thin bloodless membrane, EHY, fig. 10, which intervenes between the cavity of the yolk sac and the cavity of the uterine canal.

Between the fourteenth and sixteenth days the transverse diameter of the foetal placenta increases from 3.07 mm. to 4.80 mm., and the hilum at both periods is one-third of the diameter of the foetal placenta.

After the sixteenth day the outer wall of the yolk sac, beyond the margin of the trophoblast, undergoes further atrophy, and finally it entirely disappears.

When the diameter of the foetal placenta has increased to 7.52 mm. (fig. 11), the only portion of the external wall of the yolk sac remaining is the external hypoblast which covers the surface of the trophoblast between the hilum and the margin of the foetal placenta.

When the outer wall of the yolk sac, beyond the margin of the trophoblast, has disappeared, the remains of the yolk sac cavity, which extends from the entodermal sinus to the margin of the trophoblast (fig. 11), communicates freely with the uterine cavity, and the greater part of the internal hypoblast (from *b* to *b*, fig. 9) is exposed in the uterine canal and is bathed by the uterine fluids.

Simultaneously with the disappearance of the outer wall of

the yolk sac, the villi on the internal wall increase in size and complexity (fig. 11), and the spaces in the hilum of the placenta become larger and more tortuous, but the epithelium remains unchanged.

The rapidly changing relations which occur during the development of the ovum must have an important bearing upon the nutrition of the embryo. In the early stages, up to the end of the sixth day, whilst the ovum lies free in the uterine canal in an epithelial lined crypt which is in free communication with the uterine cavity, its pabulum must be derived from the uterine fluids by which it is surrounded, for there is no other source whence it can obtain sustenance for its continued growth.

As the crypt closes and its epithelium degenerates, it is possible that the ovum lives upon the degenerating uterine cells;¹ but no traces of the degenerating cells have been found, as yet, within the cells of the ovum; therefore, though the continued growth of the ovum and the degeneration of the uterine epithelium are coincident events, there is no definite proof that the former event is in any way dependent upon the latter.

After the uterine crypt is converted into an enclosed space and its epithelium has disappeared, and before the maternal blood lies in direct relation with the ovular tissues, two sources of nutrition are available to the growing ovum,—it must live either upon the cells of the decidua, or upon fluids which have exuded from the maternal vessels. There is no evidence that it lives on the decidual cells, and probably therefore its nutriment is derived from the maternal fluids, which are separated from the ovum by a very thin layer of decidual tissue.

Even at such an early period as the latter part of the seventh day the embryonic area, represented by the epiblast and the internal hypoblast (α to α , fig. 3) which covers it, is one of the portions of the ovum furthest removed from any direct source of nutrition. Proximally it is separated from the decidual tissues by the trophoblast, and laterally and distally by the yolk sac, therefore any nutriment which reaches it must pass either

¹ M. Duval, "Le Placenta des Rongeurs, troisième part, Le Placenta de la Souris et du Rat," *Journal de l'Anatomie et de la Physiologie*, année 1891, No. 1, Janvier-Février, p. 35.

through the trophoblast or through the yolk sac. It is improbable that it passes through the trophoblast, for that portion of the ovum is a solid mass of epiblastic tissue. The outer wall of the yolk sac, however, is a thin epithelial membrane, through which maternal fluids may readily pass by endosmosis into the cavity of the yolk sac, where they come into direct contact with the hypoblast of the embryonic area, and having passed through it, they may be absorbed by the germinal epiblast. Thus *at an early period the yolk sac becomes a nutritive agent through which pabulum is transmitted to the embryonic area.*

During the eighth day the maternal blood is brought into direct relation with the ovum by the disappearance of the decidual tissue in the immediate neighbourhood of the external hypoblast. As the result of this disappearance the trophoblast and external hypoblast become the internal walls of sinus-like spaces which intervene between the ovum and the decidua. These spaces are filled with maternal blood, which circulates round the outer wall of the yolk sac, over the superficial surface of the trophoblast and in spaces which are developed by vacuolation within the trophoblast.

During the eighth, ninth, and tenth days, whilst the epiblastic cavity is developed and transformed into the amniotic cavity, the trophoblastic cavity appears and is obliterated, the coelom is formed, and the allantois grows out from the posterior end of the primitive streak, the only source whence the embryonic area can derive its nutriment is the yolk sac, and the nutriment in the yolk sac must have entered it by endosmosis through its outer wall. The blood which circulates in the trophoblast during the eighth, ninth, and tenth days serves only for the nutrition of that portion of the ovum. It is certainly possible that nutritive fluids might be transuded from the blood circulating in the proximal portion of the trophoblast into the cavity in the distal portion of the trophoblast, and thence they would pass to the embryonic area, but the area through which such exudation might occur is so extremely small (figs. 4, 5, and 6) that this source of nutrition may be eliminated from consideration, more especially as during the latter part of the ninth day the cavity of the trophoblast is obliterated, and the blood in the trophoblast is separated from the embryonic area

by a thick layer of trophoblast, the coelomic cavity, and the amnion (fig. 7).

It might be suggested that the allantois absorbs nutriment from the coelom into which it projects on the ninth day. It is to be noted, however, that during the ninth day the allantois is a solid mass of cells, absolutely devoid of blood-vessels, and in addition, that any nutriment present in the coelom must have entered it either through the trophoblast or through the yolk sac. As before stated, it is improbable that it passes through the trophoblast, for by the time the allantois has become a distinct organ, the distal portion of the trophoblast has been forced away from the epiblast and compressed against the vascular proximal trophoblast by the extension of the coelom (fig. 7). Thus a thick wall of dense trophoblastic tissue intervenes between the coelom and the maternal blood in the spaces of the proximal trophoblast. During the eighth, ninth, and tenth days, therefore, *the yolk sac is the only organ through which nutriment can be conveyed to the embryonic area*, and it is especially adapted to the nutritive function which it performs. Its outer wall is reduced to an extremely thin cellular membrane, which lies in direct contact with the maternal blood, and there can be but little doubt that through this thin membrane endosmosis occurs; indeed, the continuance of the distinct space between the two walls of the yolk sac must be dependent upon fluid pressure which is maintained by osmosis from the maternal blood.

After the nutritive fluid has entered the yolk sac it is at once in contact with the hypoblast of the germinal area, which must not only seize upon some portion of it (the fluid) for its own maintenance, but it must also transmit another portion to the embryonic epiblast which it encloses (fig. 7).

Whether the nutriment which is passed through the embryonic hypoblast to the epiblast is transmitted by osmosis or secretion it is impossible to say, but it is to be noted that at this period the embryonic hypoblast cells are flattened, and that they present none of the usual appearances of secretive cells.

Between the eleventh and fourteenth days nutriment may pass to the embryo either through the yolk sac or by the allantois from the placenta. No doubt a large amount passes

from the maternal blood in the trophoblastic spaces to the foetal blood in the mesoblastic villi which have penetrated the trophoblast and insinuated themselves between its spaces. It is not probable, however, that the whole of the foetal nutriment is transmitted to the embryo at this period by the allantois, for there is still a free circulation of maternal blood round the external wall of the yolk sac; and although, on account of the folding of the embryo and the formation of the vitello intestinal duct, the nutritive fluids which have passed by osmosis into the yolk sac no longer come into such direct contact with the embryonic area (fig. 9), provision has been made for the rapid absorption of the nutriment by the extension of the area of the inner wall of the yolk sac, which has been thrown into folds and projected into villi, and its conveyance to the embryonic area is provided for by the vascularisation of this wall through the formation *in situ* of the tributaries of the vitelline vessels.

After the fourteenth day the ramifications of the vascular mesoblastic villi in the trophoblast are rapidly increased and extended, and as by the thinning of the intervening walls between the foetal and maternal blood the relationship between the two fluids becomes more intimate, it might, *a priori*, be supposed that the nutritive function of the yolk sac would terminate, and that the foetal nutrition would be carried on entirely by the allantois.

Undoubtedly during this period the circulation of the maternal blood round the outer wall of the yolk sac rapidly diminishes and finally ceases as the decidua reflexa atrophies, consequently the function of the outer wall of the yolk sac as an osmotic membrane terminates; but as the area of the external hypoblast in intimate relationship with the maternal blood diminishes in one region, it is increased in another. Simultaneously with the cessation of the circulation in the decidua reflexa, numerous diverticula grow from the entodermal sinus into the hilum of the placenta, where they lie between the mesoblast and the trophoblast, in relation on one side with the maternal and on the other with the foetal vessels.

This peculiar feature of development suggests the idea that not only is the nutrition of the embryo dependent for a time entirely on the yolk sac, but that the yolk sac is also an

important nutritive agent in the later periods of development, during which its hypoblastic walls either select nutritive substances other than those which pass by direct transfusion into the foetal vessels in the placental area, or they modify the materials which are passed through them in such a manner as to especially adapt them to the use of the rapidly growing embryo.

After the sixteenth day the problem becomes complicated by the disappearance of the whole of the outer wall of the yolk sac, except that portion which is overlapped by the trophoblast, between the points α and α (fig. 9). Apparently, however, the function of the inner wall of the sac does not cease with this occurrence, for the folds and villi on its surface increase in size and complexity (fig. 11), and as the hypoblast lined spaces in the hilum of the placenta also increase both in extent and tortuosity, it is to be presumed that they also remain functional, but any fluid which passes through them into the entodermal sinus, with which they still communicate, is no longer retained in the yolk sac; as soon as it passes beyond the margin of the trophoblast, point α , fig. 11, it is discharged into the uterine canal. This circumstance suggests the possibility that the inner wall of the yolk sac and the spaces in the hilum of the placenta are not structures which transmit nutriment into the foetal blood, but excretive agents which eliminate effete products from the foetal circulation.

Methods of histological examination will not alone suffice to decide finally whether this is the case or not. When it is remembered, however, that in the early stages the only possible way in which nutriment from the maternal blood can reach the embryonic area is through the yolk sac, and that, when the circulation of the maternal blood round the outer wall of the yolk sac ceases, the cavity of the sac is extended into the placental area so that its intimate relationship with the maternal blood is to a certain extent maintained, I think it must be admitted that the phenomena of development point to the conclusion that the nutritive function of the yolk sac is probably maintained, and that, after the disappearance of the outer wall of the yolk sac, the villous folds on the inner wall absorb nutriment from the fluids which are passed into the uterine canal, both from the uterine glands and from the spaces in the hilum of the placenta.

So far as I am aware, the invasion of the placenta by diverticula from the yolk sac has not been observed in any mammals except the rat and the mouse, but in the majority of mammals the allantoic diverticulum from the hind-gut extends through the mesoblastic portion of the allantois into the placental area. This diverticulum is generally considered to be "a urinary bladder which, precociously developed and enormously extended in the embryo, has acquired respiratory and nutritive functions,"¹ not, however, by means of its hypoblastic lining, but by the splanchnic mesoblast which covers it. The phenomena observable during the development of the rat and the mouse point to a somewhat different conclusion, viz., that it is a matter of importance to the embryo that the foetal hypoblast should gain an intimate relationship with the maternal blood; but, apparently, as the hypoblast may enter the placenta either from the wall of the yolk sac or from the hind-gut, the region whence the placental hypoblast is derived is a matter of indifference.

It must be noted, that although in the rat and mouse, after the seventh day, the foetal hypoblast maintains a close relationship with the maternal blood until the close of intra-uterine life, such close relationship is not a necessity in the early periods, for in the rabbit, where a decidua reflex is not formed, and a large part of the ovum acquires no intimate connection with the uterine wall, the upper wall of the yolk-sac, covered by a thin epiblastic layer, lies in the uterine canal, and is bathed by the uterine fluids, from which nutriment must be derived until, during the tenth day, the placental circulation is established. It is not until after the thirteenth day that the necessity for the hypoblastic diverticula in the placenta arises. It seems probable, therefore, that the function of the hypoblast which enters the placenta differs in some way from that which forms the outer wall of the yolk sac, but its histology gives no clue to the nature of this difference.

Conclusions.

(1) In the Rodentia (the rat and the mouse), as well as in the Insectivora and Marsupials, the yolk sac is an important nutritive organ.

¹ F. M. Balfour, *A Treatise on Comparative Embryology*, p. 256, London, 1881.

(2) In the rat and the mouse the yolk sac is the only foetal organ of nutrition during a certain period of development.

(3) The almost constant appearance of the hypoblast in the placental area, and the fact that it enters that area from different situations in different animals, are indications of its functional importance during intra-uterine development.

(4) The hypoblast is not merely a framework which carries the splanchnic mesoblast on its expanding surface and brings it into contact with the trophoblast; on the contrary, it is an active agent of considerable nutritive importance during the later periods of development.

DESCRIPTION OF THE FIGURES ON PLATE VIII.

Figs. 1, 2, and 9 are compounded from several sections. Figs. 3, 4, 5, 6, 7, and 8 represent individual sections; their outlines were drawn with the camera lucida. Figs. 10 and 11 are drawn from individual sections.

Alphabetical List of Reference Letters for all the Figures.

- AL = Allantois.
- AM = Amnion.
- AMC = Amnion cavity.
- C = Cephalic end of embryonic area.
- CE = Cavity of epiblast.
- COE = Coelom.
- CT = Cavity of trophoblast.
- DT = Distal trophoblast.
- E = Formative epiblast.
- EC = Enteric canal.
- EHY = External hypoblast.
- EMY = Embryonic hypoblast.
- ENS = Entodermal sinus.
- FG = Fore-gut.
- FM = Foetal mesoblast.
- IHY = Internal hypoblast.
- NC = Neural canal.
- PC = Pericardial mesoblast.
- PS = Primitive streak.
- PT = Proximal trophoblast.
- S = Hypoblast lined spaces in the hilum of the placenta.
- SM = Somatic mesoblast.

SPM = Splanchnic mesoblast.

T = Trophoblast.

TC = Cavity of trophoblast.

YS = Yolk sac.

VI = Villi of internal hypoblast and splanchnic mesoblast.

Fig. G. Longitudinal section of the ovum of a mouse at the commencement of the seventh day. $\times 112$.

Fig. 2. Longitudinal section of a mouse a little older than that represented in fig. 1. $\times 160$.

Fig. 3. Longitudinal section of the ovum of a mouse at the middle of the seventh day. $\times 170$.

Fig. 4. Longitudinal section of the ovum of a rat at the middle of the eighth day. $\times 60$.

Fig. 5. Longitudinal section of the ovum of a mouse at the ninth day. $\times 60$.

Fig. 6. Longitudinal section of the ovum of a mouse in the latter part of the ninth day. $\times 60$.

Fig. 7. Longitudinal section of the ovum of a rat at about the middle of the tenth day. $\times 70$.

Fig. 8. Mesial section of the ovum of a mouse at the eleventh day. $\times 33$.

Fig. 9. Mesial section of the ovum of a mouse at the fourteenth day. $\times 15$.

Fig. 10. Mesial section of the foetal placenta and the proximal part of the yolk sac of a mouse ovum at the sixteenth day. $\times 12$.

Fig. 11. Mesial section of the foetal placenta and the proximal part of the yolk sac of a mouse at about the eighteenth day. $\times 10$.

THE COMPARATIVE ANATOMY OF THE MUSCLES
AND NERVES OF THE SUPERIOR AND INFERIOR
EXTREMITIES OF THE ANTHROPOID APES. By
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Anatomy, University of Edinburgh.* PART II. (PLATE IX.)

MYOLOGY OF THE INFERIOR EXTREMITY.

Gluteal Region.

Gluteus Maximus.—In each of the Apes this muscle was flat and thin compared with the corresponding muscle in Man.¹ Except in the Orang it was a continuous muscle, extending from the posterior part of the iliac crest to the ischial tuberosity, but the interval between the gluteus maximus and tensor fasciæ femoris muscles, which was completed by the gluteal aponeurosis, was larger than in Man.

Only in the case of the Orang was this muscle distinctly segmented. In it, the upper and lower parts were separated from each other by a wide hiatus; but in all the animals the lower part of the muscle arose from the ischial tuberosity in close contact with the ischial origin of the biceps flexor cruris. Not having been able to make a complete examination of this muscle in the Gibbon, I am not in a position to make a definite statement regarding the whole muscle, but in the portion which was present I could determine that the anterior fibres were separated from the remainder of the muscle except at their insertion, and they constituted the sole representative of the tensor fasciæ femoris. In the Orang there was no trace of the tensor fasciæ femoris muscle, but in the Gorilla and Chimpanzee it was present as a feeble muscular slip inserted into the fascia of the thigh close to the insertion of the gluteus maximus. These animals therefore provide illustrations of the fact that the gluteus maximus consists originally of three

¹ Dr Symington accounts for the prominent appearance of the anus in Apes, as compared with Man, by the flattened form of this muscle in the former, and its prominence in the latter.—*Rep. British Assoc.* 1890, p. 630.

segments, united to a certain extent by a fascia. The lower part of the muscle arising from the ischial tuberosity may be regarded as the displaced agitator candaë, while the gluteus maximus proper and the tensor fasciæ femoris are more or less separated from each other. In all the animals the insertion was much lower down on the femur than in Man. In the Gorilla and Chimpanzee the muscular fibres almost reached the external condyle of the femur: in the Orang they ceased about the middle of the external intermuscular septum, and in the Gibbon they did not extend beyond the upper half of the shaft of the femur on its posterior aspect.

Gluteus Medius.—In all the animals this muscle was much more powerfully developed than the gluteus maximus, and in every case it was quite distinct from the gluteus minimus, although its lower margin was always intimately blended with the pyriformis. Throughout the series its origin and insertion were fairly similar and closely corresponded with what we find in Man. In the Chimpanzee we may note that the insertion was partly split by an upward prolongation of the vastus externus, on the external surface of the great trochanter.

Gluteus Minimus.—In each animal this muscle was distinct from the gluteus medius, but it varied in size, being much larger in the Gorilla and Chimpanzee than in the Orang and Gibbon. The muscle was divisible into three parts in the Chimpanzee. Two of these were anterior and posterior, while the third fasciculus lay under cover of the anterior portion. In the Gorilla there were anterior and posterior portions, the former much larger than the latter, which arose from the dorsum ilii along the lower margin of the great sacro-sciatic foramen, and ran outwards to blend with the rest of the muscle near its insertion. In both the Gibbon and Orang it was a small muscle. In all of these Apes the insertion was into the anterior border of the great trochanter. In association with the anterior margin of the gluteus minimus we require to note the presence of a muscular fasciculus which was quite distinct from it in the Chimpanzee and Orang, but blended with it in the Gibbon and Gorilla. This fasciculus was the scansorius muscle which arose from the dorsum ilii between the gluteus minimus and the tensor fasciæ femoris, and was inserted into the anterior margin

of the great trochanter close to the lower edge of the tendon of insertion of the gluteus minimus.

Pyriformis.—The tendon of this muscle was always a well-marked feature in relation to the lower margin of the gluteus medius, but the muscular parts of the two muscles were usually intimately fused with each other. It took origin from the anterior surface of the sacrum, extending as high as the second sacral segment in the Chimpanzee and Orang, and as low as the fifth sacral segment in the Chimpanzee and Gorilla. (In the Gibbon the origin had been removed in the plane of section.) Its insertion was into the upper margin of the great trochanter, close to the posterior border of the gluteus medius.

Obturator Internus.—The obturator internus was a well-developed muscle, with a flattened tendon playing over the osseous margin of the small sciatic foramen. Between the tendon and the bone there were synovial surfaces, but the tendon was not so distinctly plicated nor the cartilaginous surface of the bone raised in ridges as in Man. In all the animals there was more or less fusion between the tendons of the obturator internus and obturator externus close to their points of insertion, and the insertion of the former was always above and in front of the tendon of the latter. Associated with the upper and lower margins of the obturator internus tendon there were muscular fibres which constituted the gemelli muscles.

Gemelli.—In the Gorilla, Chimpanzee, and Orang, the superior gemellus was attached to the ischium in the position of the ischial spine, which was rudimentary. In the Chimpanzee the superior gemellus was larger than the inferior, but in the Orang this proportion was reversed. In the Gibbon, on the other hand, although there were no fibres attached to the ischium such as would correspond to the superior gemellus, nevertheless a small muscular fasciculus could readily be raised from the surface of the tendon of the obturator internus. When the position of this fasciculus is considered in relation to an undoubted inferior gemellus which was placed subjacent to the same tendon and took origin from the outer border of the ischial tuberosity, we are fairly warranted in concluding that these superficial fibres represented the superior gemellus detached from its true osseous connection to the ischium. In each animal there was

a distinct inferior gemellus, which was as a rule difficult to completely isolate from the quadratus femoris, but it was always more or less inserted into the lower border of the tendon of the obturator internus. With the assumption of the erect attitude and the increased size of the pelvic outlet, the levatores ani muscles of Man have become more important than in the lower animals. Probably this is accompanied by an increase in the size of the ischial spine and the attachment of some superficial fibres of the obturator internus to its outer side, thereby constituting the gemellus superior.

Quadratus Femoris.—This was a separate and distinct muscle throughout the series,—that is, separate from the upper border of the adductor magnus, which slightly overlapped it in the Orang; but in the Gibbon the quadratus femoris overlapped the adductor magnus. As already indicated, the inferior gemellus was closely associated with the upper border of the quadratus femoris, in some cases completely fused. In the Chimpanzee, Orang, and Gibbon, its insertion was somewhat peculiar, consisting of a part inserted vertically into the posterior surface of the great trochanter, and another part inserted horizontally into the posterior surface of the femur along a line passing outwards from the small trochanter. In the Gorilla, only the vertical portion of this insertion was present.

Obturator Externus.—This muscle followed the usual arrangement found in Man; but as it approached its insertion, it fused more or less with the tendon of the obturator internus. In each case it was inserted into the digital fossa on the inner surface of the great trochanter.

Hamstring Muscles.

Biceps Flexor Cruris.—In each of the animals this muscle presented two heads—ischial and femoral; but in no case did they unite to form a single belly. On the contrary, the two heads remained distinct, and only in the Gibbon did the muscular fibres of the femoral head join the tendon of the ischial head. In the other three animals there was only fusion to a variable extent between the two tendons of insertion. In my Orang the ischial head did not possess the insertion into the lower third of

the femur as described by Church.¹ There were always two distinct insertions for these two heads; the long or ischial head being inserted into the head of the tibia on its outer side, while the short or femoral head was inserted into the head of the fibula, being partly fused with the tendon of the long head, and moreover it sent a wide aponeurotic expansion to join the fascia over the external head of the gastrocnemius. In the Orang an expansion from the long tendon joined the external surface of the capsule of the knee-joint.

Semitendinosus.—This muscle had the usual origin from the tuber ischii in common with the long head of the biceps, and in the Chimpanzee it was also fused with the upper surface of the semimembranosus. The line of insertion into the inner surface of the shaft of the tibia was in all cases on a plane posterior to the insertions of the gracilis and sartorius, but in the Chimpanzee and Gibbon it was lower down than the insertion of the gracilis. It is to be noted that the insertion of this muscle as well as that of the gracilis and sartorius was considerably lower down on the shaft of the tibia in the Gibbon, Orang, and Chimpanzee than it was in the Gorilla. In the three animals first named a faint tendinous intersection was visible midway in the length of the belly of the muscle.

Semimembranosus.—Contrasting this muscle in the various Apes with that of Man, the only noteworthy features in connection with it were found in relation to its tendon of insertion. This was a definite rounded structure inserted in the usual way, but not contributing any expansions to the posterior ligament of the knee-joint or to the deep fascia of the leg except in the Gorilla, in which both of these expansions were present, although of feeble dimensions.

MUSCLES ON THE ANTERIOR ASPECT OF THE THIGH

Psoas Parvus.—In each of the animals this muscle was present. It was smaller than the Psoas magnus, and arose from the sides of the bodies of the last dorsal and the upper one or two lumbar vertebræ. In each, its insertion was into the iliopectineal line, farther forward in the Chimpanzee than in the

¹ Church, *Nat. Hist. Rev.*, 1862.

Orang and Gorilla. There was no opportunity of examining this muscle in the Gibbon, but according to Kohlbrügge¹ it arises from the first three lumbar vertebræ in *H. agilis*.

Ilio-psoas. (Iliacus and Psoas Magnus.)—This large composite muscle had very similar connections throughout the series. The iliacus occupied the iliac fossa, while the psoas magnus arose from a varying number of vertebræ:—in the Gorilla, from the bodies of the first three lumbar vertebræ, with their intervertebral discs, the transverse process of the third lumbar vertebra and the iliac crest external to that point: in the Chimpanzee, from the bodies and intervertebral discs of the four lumbar and the first sacral vertebræ, also from the transverse processes of the lumbar vertebræ: in the Orang, from the last (12th) dorsal and all (4) the lumbar vertebræ: in the Gibbon, an additional origin was observed, viz., from the outer side of the tendon of origin of the rectus femoris. This particular origin was also seen by Kohlbrügge. The insertion of these combined muscles corresponded to the condition found in Man, being into the small trochanter and into the shaft of the femur for a short distance below it.

Sartorius.—In every case this muscle was attached to the anterior border of the ilium lower down than in Man, being situated between the iliacus and scansorius, and close to the origin of the rectus femoris. In all, it was a well-defined ribbon-shaped muscle, which crossed the thigh obliquely to reach its inner side, along which it descended posterior to the internal condyle of the femur. Then turning forwards, it was inserted into the inner surface of the shaft of the tibia superficial to the insertions of the gracilis and semitendinosus muscles, and sent an expansion to the deep fascia of the leg.

Quadriceps Extensor Cruris.—In all the animals this compound muscle was very readily separated into its component parts, although the separation could not be so completely effected as in Man. The origin of the rectus femoris was double in every case except the Gibbon, in which it arose from a single tendon, and Macalister² has stated that a similar condition is

¹ *Loc. cit.*

² "Muscular Anatomy of Tasmanian Devil and Wombat" (*Ann. and Mag. Nat. Hist.*, vol. v., 4th series).

found in several of the Marsupials, although this remark does not apply to all the Marsupials, in many of which it is also double.¹

In those Anthropoids in which the origin was double, it presented more the form of an arch closely applied to the upper surface of the acetabulum, rather than two separate heads as in Man. The other factors of the muscle were well developed, and possessed the relative proportions and attachments which are characteristic of the corresponding muscles in Man. Towards their insertions these muscles were grouped round the upper border and lateral margins of the patella, which was a well-developed bone. In this way they contributed to the formation of the capsule of the knee-joint on its antero-lateral aspects. From the lower border of the patella a powerful ligamentum patellæ continued these tendons of insertion to the anterior tubercle of the shaft of the tibia.

In every case a few small but distinct pale-coloured fasciculi were found on raising the lower part of the crureus muscle from the shaft of the femur. These constituted the subcrureus muscle, and it had the usual attachments.

MUSCLES ON THE INNER ASPECT OF THE THIGH.

Pectineus.—This muscle was fairly constant in position, although it varied in width and was always a very thin stratum. It arose from the horizontal ramus of the pubis in front of the ilio-pectineal line, and extended from the ilio-pectineal eminence on the outer side to the origin of the adductor longus on the inner side. In the Gorilla and Orang this muscle abutted so closely against the adductor longus, which had a flattened instead of a rounded origin and extended for a considerable distance outwards in consequence, that it is quite easy to understand how a portion of the adductor longus might become detached and left in association with the pectineus. In this way not only would the pectineus gain in size, but it would account for that arrangement of its nerves which is sometimes found, viz., its supply by the anterior crural and obturator nerves. The insertion of the pectineus was in its usual

¹ Cunningham, *loc. cit.*

situation, viz., into the shaft of the femur immediately posterior to the insertions of psoas and iliacus.

Adductor Longus.—In the Chimpanzee this muscle had the usual rounded tendon of origin, but in the other three animals its origin was flattened and fleshy. In the Orang the proportion between the width of adductor longus and pectineus at their origins was very instructive, for, while the pectineus only measured one-third of an inch, the adductor longus measured three-fourths of an inch. As the muscle descended from its origin it underwent still further expansion, and was inserted into the linea aspera in the middle portion of the femoral shaft.

Gracilis.—This was relatively a much more powerful muscle than in Man. Its origin was very extended, usually springing from the whole length of the body of the pubis close to the symphysis, and in addition extending outwards on one or both of its rami—descending and horizontal. The course of the muscle was as usual, and it was inserted in association with the semitendinosus and sartorius. By means of a strong aponeurotic expansion into the fascia of the leg, its adducting power can be applied much lower down than in Man. This expanded aponeurosis was much more fully developed in the Orang and Gibbon than in the Gorilla and Chimpanzee, and is doubtless to be associated with the special habits of these animals, since the former pair are much more distinctively arboreal than the latter.

Adductor Brevis.—Although in each of the Apes this was a perfectly distinct muscle, taking origin from the front of the body of the pubis between the adductor longus and gracilis internally and the obturator externus externally, yet it presented considerable variety in the size which it attained in the different animals. It reached its greatest development in the Gorilla, in which at its insertion into the linea aspera it overlapped the adductor longus posteriorly, both at its upper and lower margins.

In the Chimpanzee and Orang it was actually and relatively a much smaller muscle, and in each of them it partially segmented into two portions. In both animals it was inserted posterior to the pectineus, and into the line which leads from

the small trochanter to the linea aspera. The two segments were distinct from each other until quite close to the femur, where they fused; in the Orang the inner and posterior segment, which was very slender, fused with the adductor magnus. In the Gibbon the muscle was about equal in size to the pectineus, and was in one portion, which was inserted into the femur between the pectineus and upper part of the adductor magnus, and intimately attached to the latter near to the line of insertion.

Adductor Minimus.—This muscle was very distinctly seen in the Gorilla, in which it arose from the front of the body and horizontal ramus of the pubis between adductores brevis and longus, superiorly, and obturator externus, inferiorly. It was inserted into the posterior aspect of the shaft of the femur behind the pectineus. Its upper margin was separated by a narrow interval from the quadratus femoris, and a similar interval divided its lower margin from adductor magnus. Probably the deeper of the two slips found in the Chimpanzee and Orang, and referred to under the head of adductor brevis, may represent this muscle in a transition stage; while the adhesion of adductor brevis to adductor magnus in the case of the Gibbon may indicate a still earlier stage in the segmentation of this special muscle.

Adductor Magnus.—This was in every instance by far the most powerful of the series of adductor muscles. The origin fairly corresponded to that of Man, but in the Gibbon and Chimpanzee it showed a tendency to become fasciculated. So much was this the case in the Chimpanzee that a portion of the ischial origin quite readily separated from the remainder of the muscle. This ischial head developed a rounded tendon which was inserted into the adductor tubercle on the inner condyle of the femur, and it is of great interest and importance to note that this particular portion of the adductor magnus muscle received its nerve-supply from the great sciatic nerve. Altogether it was much liker an additional hamstring muscle than an adductor, and it received its nerve-supply accordingly. Again, it was between these two distinct portions of the adductor magnus muscle that the femoral vessels passed from the front of the thigh into the popliteal space. An interesting modification of this condition of the ischial head was found in

the Gibbon. In it, the ischial head was not separable from the rest of the muscle, but it nevertheless developed a rounded tendon, by means of which it was inserted, not into the internal condyle of the femur, but into the middle of the internal supracondyloid ridge, posterior to the femoral vessels, which therefore become continuous with the popliteal vessels in the interval between vastus internus and the tendon of semi-membranosus. In the Gorilla and Orang the ischial portion of the muscle was inserted in the usual way. Indeed, the entire muscle in the Orang resembled that of Man more closely than in any of the other animals. In the Gorilla the insertion of the muscle into the linea aspera only extended as high as the lower border of adductor minimus: in the Chimpanzee it overlapped the adductor minimus to a slight extent, and in the Orang and Gibbon it ran upwards to the lower border of quadratus femoris. Lastly, in the Chimpanzee the lower fibres of the deep portion spread out on and were inserted into the greater part of the popliteal surface of the femur, extending as low down as the posterior ligament of the knee-joint. To a modified extent the same condition was present in the Orang. Now, when we consider that these particular fibres on the popliteal surface of the femur belong to that part of the adductor magnus which is innervated from the obturator nerve, there is no difficulty in understanding the channel through which this nerve reaches the posterior aspect of the knee-joint. Carried to that position in the substance of the adductor magnus, it retains its hold of the region even when the muscle has retreated, leaving the popliteal surface of the femur devoid of muscular fibres. There are many other instances of the persistence of nerves in positions where they were once associated with muscular fibre, long after these muscular end-organs have entirely disappeared, and from them the illustration under consideration derives support.

MUSCLES OF THE LEG.

Anterior Region.

Tibialis Anticus.—There was a close similarity among the several instances of this muscle throughout the series of dissec-

tions, and it intimately corresponded with the same muscle in Man. In every case there was a double tendon and a double insertion—the one into the entocuneiform, the other into the internal aspect of the base of the first metatarsal bone. Each of these tendons was the outcome of a special part of the belly of the muscle, and in the Gibbon and Chimpanzee this splitting of the muscle was present for some distance above the anterior annular ligament of the ankle-joint. There can be no doubt but that this muscle is the homologue of that which in the forearm occupies the position of the *extensores ossis metacarpi pollicis* and *primi internodii pollicis* of Man. I have already¹ endeavoured to show that these extensors of the pollex are really present under modified conditions, and therefore I am disposed to consider that the *tibialis anticus* is homologous with both of them.

Extensor Proprius Hallucis.—This muscle closely resembled its prototype in Man, both as regards its origin and insertion. In the animals under consideration, the tendon of the muscle was retained in a strong fibrous sheath in relation to the dorsum of the first metatarsal bone, and from the fact that the dorsum of the hallux is well turned over towards the tibial aspect of the foot, it is advantageously situated for acting as an abductor of the hallux as well as an extensor of the last phalanx. Many points in connection with this muscle at once recall the *extensor pollicis longus*, with which it is no doubt homologous.

Extensor Longus Digitorum.—In all essential features this muscle corresponded throughout the series, and resembled that of Man in being distributed to the four outer digits. In the case of the Orang, cross bands of connection were found between these tendons on the dorsum of the foot.

Peroneus Tertius.—There was no trace of this muscle in any of the Apes under consideration. It is characteristic of Man, and appears to be associated with the act of walking in the erect attitude. By its action the outer border of the foot is prevented from coming in contact with the ground before the inner border. In other words, when the heel touches the ground in the act of walking, the front part of the foot is steadied by the *tibialis anticus* and *peroneus tertius* muscles, and so we

¹ *Jour. Anat. and Phys.*, Jan. 1892 (Part I. of this paper).

are enabled to apply the flat sole gently to the ground. Without the peroneus tertius, the inner border of the foot would be higher than the outer border which would specially be in contact with the ground in the act of walking as is seen in the Apes.

In a recent paper,¹ Mr Ramsay Smith deals with this muscle, and from clinical observations he concludes that the peroneus tertius muscle prevents the foot from coming down *flop* when the heel is placed on the ground in the act of walking; in other words, it assists in preventing "spasmodic" extension of the ankle-joint in ordinary walking. He also considers that the peroneus tertius helps in maintaining the erect attitude, and believes that these reasons explain "how the peroneus tertius muscle is the peculiar property of the human subject."

Extensor Brevis Digitorum.—This muscle was well represented in each animal. It had the usual four tendons inserted into the four inner digits; that for the hallux being attached to the base of the first phalanx; those for the other three digits becoming attached to the tendons of the long extensor. The innermost fasciculus of the muscle was almost a separate muscle on account of its transverse course inwards to reach the base of the first phalanx of the hallux. Cunningham² says:—"Ruge³ traces with great ability the history of this muscle. It belongs originally to the peroneal group of muscles, and in the *Monotremata* it may be observed to arise entirely from the fibula. Its progress as it passes down to the dorsum of the foot can be traced step by step through the mammalian series. First one belly descends, then another, and so on until the entire muscle gains the dorsum of the foot as in Man."

External Region.

Peroneus Longus.—In every case this muscle was well developed, and presented the usual origin, course, and insertion with which we are familiar in Man, except that in all the animals its insertion was limited to the base of the first metatarsal bone. In connection with this muscle, it is well to remember the hypothesis advanced by Ruge,⁴ who concludes

¹ *Edin. Med. Jour.*, Jan. 1892.

² *Loc. cit.*

³ "A Research into the Group of Extensors of the Leg and Foot of Mammalia," *Morph. Jahr.* 1880.

⁴ *Loc. cit.*

that its tendon was originally attached to the base of the fifth metatarsal bone, and that its progress inwards across the sole of the foot is due to its coming more and more in contact with the plantar ligaments. Presumably, therefore, it reaches its most specialised condition in the feet of the Anthropoid Apes, and its accessory slips to the internal cuneiform bone, and the base of second metatarsal bone as seen in Man, may be considered as reversionary stages tending towards a reproduction of its original condition.

Peroneus Brevis.—Only in the Orang was there any marked deviation from the usual type of this muscle. In it, the tendon split into three portions. The most slender of the three was inserted into the posterior surface of the projecting tubercle of the fifth metatarsal bone. The other two were of equal size, and of these one was inserted into the outer side of the base of the fifth metatarsal, the other ran forwards in a fibro-synovial sheath on the dorsum of the fifth digit, and joined the outer side of the common extensor tendon to that digit. This last insertion is most instructive. In the Thylacine,¹ the extensor brevis digitorum sends a tendon to the little toe, and Ruge² is of opinion that the Peroneus brevis is originally the outermost tendon of the extensor brevis digitorum. The present dissection provides confirmatory evidence of this supposition.

If examined side by side it must now be apparent that the extensor brevis digitorum with the peroneus brevis forms a complete muscle, sending a tendon to each of the five digits. Each of the four outer tendons becomes blended with the corresponding tendons of the long extensor muscle, while that for the hallux is inserted into the base of the first phalanx of that digit. It will be remembered that the extensor profundus digitorum (extensor indicis) of the hand of the Gibbon presented tendons inserted into the index, medius, and annularis digits. It therefore seems to me that the peroneus brevis and extensor brevis digitorum represent together such a muscle as has been described in the upper limb under the name of extensor profundus digitorum, and of which the sole remaining portion in Man is the extensor indicis. In the foot of Man and of the Anthropoid Apes the homologous

¹ Cunningham, *loc. cit.*

² *Loc. cit.*

muscle is well preserved, although to a great extent moved from the fibular aspect of the leg to the dorsum of the foot. For these reasons I am not inclined to regard the innermost segment of the extensor brevis digitorum pedis as homologous with the extensor primi internodii pollicis (extensor brevis pollicis), but rather to look upon it as a muscular slip, of which the homologue has disappeared from the hand of the Anthropoid Apes as well as of Man.

Posterior Region.

Gastrocnemius.—In each animal this was a distinct muscle arising from two heads which fused in the lower part of the leg to become attached to the Tendo Achillis. In no instance was there the same proportionate development of muscular fibre as in Man, and hence the calf of the leg was very flat. In the Gibbon a sesamoid bone was developed in connection with each tendon of origin. In the Chimpanzee the inner head came into intimate relation with that part of the adductor magnus which is inserted into the popliteal surface of the femur, and it rested upon but did not take origin from the posterior ligament of the knee-joint. In the Orang, on the other hand, the inner head derived fibres of origin from the posterior ligament of the knee-joint; and in the same animal the outer head was placed superficial to the condylar origin of the outer or fibular segment of the flexor longus digitorum. In the Gorilla and Chimpanzee the muscular fibres from the inner head extended farther down the leg than those from the outer head.

The *Plantaris longus* muscle was absent from all the four animals.

Soleus.—In each of the animals this muscle arose from the posterior surface of the head of the fibula by a circumscribed tendon, which, in the case of the Orang, was intimately connected with the outer head of the gastrocnemius. In the Chimpanzee a few additional fibres arose from an aponeurosis attached to the popliteal line on the tibia. In each case it was inserted into the deep surface of the Tendo Achillis, the muscular fibres extending close down to the os calcis.

To the Tendo Achillis were attached the soleus and gastrocnemius muscles after the manner indicated. As a

separate structure it could scarcely be said to exist, for it was not clear of muscular fibres until quite close to its line of insertion into the posterior surface of the os calcis. In every case a synovial bursa intervened between the tendon and the bone. The line of insertion was very oblique in the Orang and Gibbon, the result being that the heel was raised from the ground, the outer border of the foot depressed, and the inner border of the foot elevated. Clearly this arrangement harmonises with what we know of the habits of these animals in which the sole of the foot is not completely applied to the ground in the act of walking. Indeed, they rarely adopt this mode of progression. In the Gorilla and Chimpanzee, on the other hand, which spend a considerable part of their time on the ground, the insertion of Tendo Achillis was more akin to what is found in Man, and to a considerable extent they can apply the sole of the foot to the ground.

Popliteus.—In each animal this muscle was well represented. In the Gorilla and Gibbon it arose by a single-rounded tendon as in the case of Man; in the Chimpanzee, there were two origins, one a rounded tendon as in Man, the other from the capsule of the knee-joint immediately behind the external condyle of the femur. In the Orang there were also two origins, for, in addition to the usual rounded tendon, there was a second strong tendon which also arose within the capsule of the knee-joint and was attached to the upper and outer part of the head of the fibula. The nerve of supply in each case corresponded with that of Man.

Flexor Longus Digitorum—*Flexor Longus Hallucis*.—It will be best to examine these two muscles together, on account of the intimate connections which existed between their tendons in the sole of the foot. In the Gorilla these two muscles in all their details very closely resembled the conditions found in Man, but in the other animals the differences were very pronounced. A careful examination showed that these two muscles at one time formed a continuous stratum—a condition which is still present in the Orang. This stratum divides into tibial and fibular segments, which afterwards specialise into flexor longus digitorum and flexor longus hallucis respectively. In the Orang the fibular segment possesses a strong condylar origin from the external condyle of

the femur subjacent to the outer head of the gastrocnemius. From each of these segments powerful tendons resulted, and they entered the sole of the foot to be distributed to the digits in the following manner:—In the Gibbon the fibular segment (flex. long. hall.) was the larger and more powerful of the two. Its tendon subdivided into five rounded tendons, one for each digit, where they played the part of deep or perforating tendons. The tibial segment (flex. long. dig.) was smaller than the fibular; in the foot it sent slips to augment the deep tendons already in position for the first and third digits. Further, it assisted in the formation of the superficial tendons (flex. brev. dig.) for the third, fourth, and fifth digits.

In the Orang the fibular segment provided the deep tendons for the third and fourth digits, but there was no long tendon for the hallux. The tibial segment provided the deep tendons for the second and fifth digits, augmented the superficial tendon to the fourth digit, and provided the whole of the superficial tendon to the fifth digit. In the Chimpanzee the fibular segment provided deep or long tendons for the hallux, third, and fourth digits. The tibial segment provided deep or long tendons for the second, third, fourth, and fifth digits, but those for the third and fourth digits were very small.

In the Gorilla, as already stated, the fibular segment provided the long tendon for the hallux, and sent a strong slip to join the tendon of the tibial segment prior to its subdivision for the second, third, fourth, and fifth digits, for which it provided the deep or perforating tendon.

		Deep or Long Tendons. Digits.	Superficial Tendons. Digits.
Gibbon,	• { Fibular segt. Tibial segt.	1, 2, 3, 4, 5 1, 3,	3, 4, 5
Orang, .	• { Fibular segt. Tibial segt.	3, 4, 2, 5	4, 5
Chimp.,	• { Fibular segt. Tibial segt.	1, 3, 4, 2, 3, 4, 5	
Gorilla,	• { Fibular segt. Tibial segt.	1, (strong slip) 2, 3, 4, 5	

From this tabular arrangement it will readily appear that the tendency is for the fibular segment to become restricted to the hallux, except for the slip of communication with the tendon of the tibial segment, *i.e.*, it specialises into flexor longus hallucis; while the tibial segment loses its association with the superficial flexors, and becomes the true flexor longus digitorum.

Lumbricales.—In each animal there were four of these muscles, and, with the exception of the innermost, each arose from contiguous sides of two deep tendons. In the Orang only the second lumbrical had these attachments, all the others arising from the tibial side of a single tendon. Their insertions were similar to those of the corresponding muscles in Man.

Tibialis Posticus.—In each instance this muscle lay subjacent to the flexor stratum already described. There were no outstanding features of difference in its origin compared with Man, and in all the animals it was inserted into the lower part of the scaphoid bone, sending, in addition, a slip which joined the sheath of the peroneus longus in the Orang; the sheath of the peroneus longus and plantar ligaments in the Gibbon; the meso- and ecto-cuneiform bones in the Chimpanzee; and the ecto-cuneiform bone in the Gorilla.

MUSCLES OF THE FOOT.

In continuing this comparative statement, I shall adhere to the method adopted in the case of the hand, and discuss each muscle as it appears in the course of an ordinary dissection of the human foot. The facts noted with regard to the layers of superficial and deep fascia do not require special discussion, so that we may at once proceed to an examination of the various muscles, taking them in the order indicated.

Flexor Brevis Digitorum.—This muscle occupied its well-known position, subjacent to the central portion of the plantar fascia. In the Gorilla and Orang the origin was chiefly from the os calcis, and in the latter animal the calcaneal origin was so much to the inner side as to be to some extent under cover of the origin of abductor hallucis. In the Chimpanzee and Gibbon there was the usual calcaneal origin, but, in addition, there was a distinct head of origin from the plantar aspect of

the undivided tendon of the flexor longus digitorum (tibial segment); and in the Chimpanzee there was almost continuity between the muscular fibres of the flexor longus digitorum and those of this deep head of the flexor brevis digitorum. The number of tendons which this muscle produced also varied.

In the Gorilla and Orang there were only three, viz., for the 2nd, 3rd, and 4th digits, that for the 4th digit of the Orang being a mere adjunct to the much larger portion which joined it from the tibial segment of the flexor longus digitorum.

In the Chimpanzee there were four tendons—two from each head of the muscle. Those from the superficial head were distributed to the 2nd and 3rd digits; those from the deep head being very slender, and distributed to the 4th and 5th digits.

In the Gibbon, the superficial head produced a single tendon for the 2nd digit; the deep head produced three tendons for the 3rd, 4th, and 5th digits, that for the last-named digit being a mere thread. As regards the insertions of these tendons, they were exactly like those of the flexor sublimis digitorum in the hand.

We may thus trace a gradual process of development whereby the number of tendons arising from the calcaneal origin increases. Thus, in the Gibbon there was one tendon for the 2nd digit; in the Chimpanzee there were two tendons for the 2nd and 3rd digits; in the Orang there were three tendons for the 2nd, 3rd, and 4th digits (that for the 4th digit being very feeble); in the Gorilla there were three tendons for the 2nd, 3rd, and 4th digits.

Accessorius.—In the Orang and Gibbon this muscle was entirely absent, and although found in the Gorilla and Chimpanzee it was very feebly developed. In both it was attached to the os calcis, but quite on the outer side of that bone in the Chimpanzee. In the Chimpanzee it was inserted into the outer side of the tendon of flexor longus digitorum prior to its junction with flexor longus hallucis, while in the Gorilla it was inserted close to the point of junction between these two tendons.

Abductor Hallucis.—There was a considerable amount of similarity in this muscle throughout the series. In all of the animals its origin was from the os calcis on its under and inner aspects. In the Orang this calcaneal origin overlapped the origin of flexor brevis digitorum so much that it came in contact

with the abductor minimi digiti. The general origin included fibres from the lower border of the internal annular ligament of the ankle-joint, in addition to fibres from the side of the foot as far forward as the scaphoid bone. This latter origin became a separate slip in the Orang, possessing a separate insertion into the inner side of the base and proximal end of the first metatarsal bone. In every case the insertion was into the inner side of the base of the 1st phalanx of the hallux, in intimate connection with the inner head of the flexor brevis hallucis. In the Gibbon a prolongation was sent forwards to the base of the 1st phalanx of the hallux.

Abductor Minimi Digiti.—This muscle closely corresponded throughout the series so far as the origin was concerned, although in the Orang a second origin from the outer side of os calcis in front of the lesser tuberosity of that bone requires to be noted. With regard to the insertion, there was some variety due to the splitting of the tendon. In all there was an attachment to the outer side of the base of the 1st phalanx of the 5th digit; but in the Gorilla and Chimpanzee an additional slip was attached to the projecting tubercle at the base of the 5th metatarsal bone—abductor ossis metatarsi quinti. Further, in the Chimpanzee, Orang, and Gibbon a slip was sent to the shaft of the 1st phalanx. Lastly, in the Orang a small slip joined the common extensor expansion on the dorsum of the 5th digit.

Flexor Brevis Hallucis.—In discussing this muscle, we must at the outset remember that we are dealing with a foot which, so far as many of its movements are concerned, performs the functions of a prehensile or grasping organ—that is, a hand. As a consequence, the hallux is considerably separated from the rest of the digits, and we may expect to find that its intrinsic muscles have undergone modifications which cause them to deviate from the appearances the corresponding muscles present in Man, and which at the same time produce a certain approximation of their characters to those which are peculiar to the pollex. The flexor brevis hallucis affords an admirable example of these points.

In the first place, this muscle was well marked throughout the series of dissections. Moreover, in every instance it was

possessed of two perfectly distinct heads of origin—an inner and an outer. True, there was a great difference in the size of the two heads—the inner being always much larger than the outer. Nevertheless there was a remarkable similarity in the main features of each head throughout the series.

Taking the inner head of the muscle first, in each animal it arose by a strong tendinous origin from the plantar aspect of the ecto-cuneiform, and in addition from the sheath of the peroneus longus tendon and the fibrous and ligamentous structures between this and the tendon of the tibialis posticus, *i.e.*, posterior to the sheath of the peroneus longus. Running forwards, it travelled along the inner side of the hallux, and was inserted into the inner side of the base of its first phalanx. In the Gorilla and Orang there was an additional insertion into the inner border of the distal half of the shaft of the first metatarsal bone. So far, there is unanimity of opinion among observers, and it is in connection with the presence or absence of the outer head of this muscle that differences of opinion exist. According to Duvernoy and Macalister, the outer head is absent in the Gorilla, while, according to Bischoff, it is present in the Gorilla, Chimpanzee, and Gibbon. Ruge, on the other hand, believes that in the Orang it is fused with the oblique adductor. As I have already stated, I believe that my dissections show it to be present in all of these animals. In the Gorilla and Gibbon it was entirely associated with the shaft of the first metatarsal bone, but greatly reduced in size by the pressure of the proximal or oblique portion of the adductor hallucis. In the Chimpanzee it was still a small muscle, but it had extended backward to the plantar aspect of the ento-cuneiform bone, and so was crossed by the inner head as it ran to the tibial side of the hallux (fig. 3).

Its most interesting condition was found in the Orang, in which it was reduced to the size of a small lumbrical muscle; but still it arose from the plantar aspect of the base of the first metatarsal bone. In this animal it was associated with a distinct muscular slip, which looked like a third head to the flexor brevis hallucis; but a careful examination showed that this slip, although quite separate from the adductor hallucis, was in reality a modified portion of the same, because it arose

from the plantar aspect of the sheath of the peroneus longus, in close contact with the remainder of the adductor muscle. The Orang, therefore, showed a stage in the production of a spurious inner head to the flexor brevis hallucis, and the disappearance of the true inner head of the muscle.

According to Cunningham, there is no trace of the outer head in the Lemur, but the oblique adductor is largely developed. I am therefore inclined to agree with Cunningham in regarding the true outer head of the flexor brevis hallucis to be one which becomes gradually reduced in size until it may altogether disappear, rather than with Ruge, who looks upon the outer head as a derivation from the inner head of the same muscle.

Adductor Hallucis.—All through the present series of dissections this muscle was the most important factor in a stratum of muscular tissue lying superficial to the interosseous muscles, and more or less complete in every case. In each animal there was an aponeurotic septum or raphé, which extended from the tarsus to the digits, following the line of the third metatarsal bone, and being thus placed in a position to supply muscular fibres towards the inner and outer sides of the foot. The muscular fibres so arising may be named *contrahentes*, and of this group the adductor hallucis is the greatest.

Moreover, in the Gorilla and Orang it was the only representative left, a thin layer of fascia alone covering the interosseous muscles in the two outer intermetatarsal spaces. In the Chimpanzee a slender slip of muscle, arising from the outer side of the raphé above mentioned, ran downwards to be inserted into the inner or tibial side of the 1st phalanx of the little toe. The Gibbon, on the other hand, had two such slips arising from the outer side of the raphé already referred to,—one was inserted into the inner side of the 1st phalanx of the 4th digit, the other into a similar position with respect to the 5th digit. Coming now to the great *contrahens*, the adductor hallucis, we find that in every instance it arose from the inner side of the raphé, commencing as far back as the sheath of the peroneus longus, and running forwards to the level of the metatarso-phalangeal joints. With the exception of the Gibbon this muscle always presented a clear division into proximal and distal portions—*adductores obliquus et transversus*. In none of the animals did the oblique

portion extend posterior to the sheath of the peroneus longus; neither, as we have already seen, did that portion of it which in the Orang formed a spurious outer head to the flexor brevis hallucis. The distal or transverse adductor showed a decided tendency to become fasciculated by reason of an extension of its sources of origin, and in all the animals it was noted that additional slips arose from the heads of the second and third, sometimes also the fourth metatarsal bones, close to their articulation with the first phalanges. The position of this origin was either plantar or to the inner side of the head of the bone. In the Gibbon an additional contrahens muscle lay under cover of the distal portion of the adductor hallucis. It sprang from the inner side of the aponeurotic raphé, and was inserted into the outer side of the base of the 1st phalanx of the 2nd digit.

In all cases the insertion of the adductor hallucis was into the outer side of the base of the first phalanx of the hallux in intimate association with the outer head of the flexor brevis hallucis, but, as a rule, it extended beyond this on each side, and had attachments to the proximal end of the shaft of the 1st phalanx and the distal portion of the shaft of the 1st metatarsal bone.

Flexor Brevis Minimi Digiti.—We may commence the consideration of this muscle by accepting the view that originally it consisted of two heads, of which the outer tends to become more or less modified into an opponens, while the inner head becomes pressed into the sole of the foot, and is then looked upon as the "third plantar interosseous" muscle. This view is borne out by the dissections before us. In every case the inner head had sunk into the outermost interosseous space. The outer head, which represented the muscle in question, was not only difficult to separate from the interosseous muscle in the Gorilla and Chimpanzee, but in the Gibbon and Orang it could not be split so as to form a separate opponens.

In the Gorilla and Chimpanzee the portion which we call opponens was much better developed than that which was flexor brevis minimi digiti. Nevertheless, in all these animals this outer head of the flexor brevis minimi digiti was present and showed points of similarity in its origin and insertion throughout the series, the origin being from the plantar aspect

of the 5th metatarsal bone and the sheath of the peroneus longus in the Gorilla, Chimpanzee, and Gibbon, with an additional origin from the base of the 4th metatarsal bone in the case of the Orang; the insertion being always into the outer side of the base of the first phalanx of the little toe.

Opponens Minimi Digiti.—This muscle was not separable from the short flexor of the little toe in the case of the Gibbon and Orang; but in the Gorilla and Chimpanzee it became a more distinct muscle than the short flexor. It arose in common with the short flexor of the little toe, and was inserted into the outer border of the shaft of the 5th metatarsal bone for a varying distance.

Interossei.—In each of the animals this group of muscles was represented by the usual number found in Man, viz., seven. These were arranged in two sets, dorsal and plantar. Of the former there were four, and of the latter three, in each Ape. Throughout the series each dorsal interosseous muscle arose by two heads—one from each of the metatarsal bones between which it lay—with the exception of the first dorsal interosseous muscle of the Gibbon, which only arose from the inner side of the metatarsal ii.; and the first dorsal interosseous muscle of the Orang, in which the inner head of the muscle arose from the internal cuneiform bone (fig. 6). Each plantar interosseous muscle arose from a single metatarsal bone, viz., that of the digit upon which it acted, with the exception of the first plantar interosseous muscle of the Gorilla, which had a second head of origin, viz., from the second metatarsal bone (fig. 7). These plantar muscles always projected markedly into the sole of the foot, so much so that in the Gibbon the plantar interosseous muscle in the outermost interosseous space was practically on the same plane as the flexor brevis minimi digiti.

The dorsal interosseous muscles were abductors from a basal line; the plantar interossei were adductors to the same basal line.

In the Gorilla and Chimpanzee this basal line was one drawn from the tarsus to the phalanges of the index digit bisecting the second metatarsal bone. In this respect my dissection of the foot of the Chimpanzee differed from that of Champneys,¹

¹ *Loc. cit.*

in whose Chimpanzee the middle digit gave this basal line. My observation agrees with that of Bischoff,¹ while it differs from that of Duvernoy and Macalister in respect to the Gorilla. Cunningham² states that "in all the Quadrumana with two exceptions (Gorilla and Lemur), the dorsal interossei are inserted so as to abduct the toes from a line drawn through the medius, as in the case of the human hand."

We must now include the Chimpanzee among these exceptions, for it is evident that the disposition of its dorsal interossei is subject to variation. In the Orang and Gibbon, the dorsal interossei adhere to the rule which prevails among Quadrumana, i.e., they abduct the toes from a line drawn through the medius digit, and in this respect their hands and feet resemble each other, and correspond with the hand of Man. Again, in the Chimpanzee and Gorilla, the dorsal interossei are arranged as in the foot of Man.

If now we turn for a moment to the habits of these animals as affording a probable explanation of this change in the middle or basil line of the foot, we shall find that the Gorilla and Chimpanzee are not only less arboreal in their habits than the Orang and Gibbon, but when on the ground they can apply a considerable portion of the sole of the foot to the ground, whereas the Orang and Gibbon merely rest on the outer border of the foot. It would appear, therefore, that so long as the foot remained distinctly a grasping organ, the arrangement of its basil line for abduction and adduction harmonised with that of the hand, but when the sole of the foot becomes more and more applied to the ground, and the organ is thus utilised for support and progression, its basal line moves inwards so as to become associated with the second digit, at which the freedom of movement is maintained after the third digit has become applied more directly to the ground. Notwithstanding this difference of position as regards the basal line of the foot, in all of these animals the medius digit is the longest.

The foot of the Gorilla presents a most interesting condition in regard to its dorsal interosseous muscles, for in them we may

¹ "Beiträge zur Anatomie des Gorilla," *Aus den Abhandlungen der K. bayer Akademie der Wiss.*, ii., Bd. clxiii., Abth. iii.

² *Loc. cit.*

see the transition stage whereby the basal line for the movements of abduction and adduction is transferred from the medius to the index digit (fig. 7). The two muscles which occupy the second intermetatarsal space, viz., dorsal interosseous ii. and plantar interosseous i., have each two heads of origin. Now, if dorsal interosseous ii. were to lose its origin from metatarsal iii., then the basal line would be the medius digit; whereas if plantar interosseous i. were to lose its origin from metatarsal ii. then the basal line would be the index digit. I examined this point very carefully in both feet of the Gorilla. In the right foot the condition was as depicted in fig. 7, but in the left foot of the same animal, plantar interosseous i. had a very much smaller attachment to the second metatarsal bone. Indeed it had almost arrived at the condition depicted in fig. 8, which represents the foot of the Chimpanzee. In it the first plantar interosseous muscle had no attachment to the second metatarsal bone; or, in other words, the basal line had become transferred from the medius to the index digit. I believe that it is owing to variable conditions of the two muscles in the second intermetatarsal space of the Gorilla's foot that different observers have made conflicting statements regarding the basal line of the foot, some placing it at the medius digit and others at the index digit. By comparing the feet of the Gorilla with each other and with the foot of the Chimpanzee, I feel that I am fully justified in placing the basal line of the Gorilla's foot at the index digit.

THE NERVES OF THE INFERIOR EXTREMITY.

Lumbar Plexus.—Throughout these dissections the mode of formation of this plexus was similar to that found in Man, and it consisted merely of a series of loops. Not having been able to examine this plexus in the Gibbon, I find on referring to Kohlbrügge¹ that it practically assumes the same form in this animal. There is, however, one notable difference in that no loop of connection is represented between the first and second lumbar nerves of the Gibbon. While the general form of the plexus and the number of nerves entering into its composi-

¹ *Loc. cit.*

tion were closely alike in all the animals, still there were marked differences in the mode of origin of the various branches of distribution. This was evidently due to the fact that while the Gorilla and Gibbon possess five lumbar nerves, the Chimpanzee and Orang have only four lumbar nerves. As a consequence, the nerves arising from the plexus were very similar in the two sets of animals, as will readily be seen from the accompanying table:—

	Gorilla.	Gibbon.	Chimpanzee.	Orang.
Ilio-inguinal, . .	1	1	1	
Genito-crural, .	1, 2	2	1	1
Ext. cutaneous, .	2, 3	2, 3	2, 3	1, 2
Anterior crural, .	2, 3, 4	2, 3, 4	1, 2, 3	1, 2, 3
Obturator, . .	2, 3, 4	3, 4	2, 3, 4	1, 2
Lumbo-sacral cord,	4, 5	4, 5	4	3, 4

The *psoas parvus* muscle received its nerve-supply as follows:—In the Orang, from the loop between D. 12 and L. 1; in the Chimpanzee, from D. 13; in the Gorilla, from the loop between L. 1 and 2. The *psoas magnus*, on the other hand, as a rule, received several branches from the upper two or three lumbar nerves, and also from the anterior crural nerve in the case of the Chimpanzee.

Genito Crural Nerve.—This nerve arose high in the plexus and came forward through the substance of the *psoas magnus* and then descended on the surface of the *psoas parvus* to follow its customary distribution as a cutaneous nerve to the genital organs and upper part of the front of the thigh.

External Cutaneous Nerve.—In all the animals, with one exception, this nerve arose from L. 2 and 3. In the Orang, it sprang from L. 1 and 2. It pursued the usual course across the surface of the *iliacus* muscle and entered the thigh close to the inner side of the anterior superior spine of the ilium, and under cover of Poupart's ligament. In the thigh it was distributed as a cutaneous nerve on its anterior and outer aspects.

Anterior Crural Nerve.—In each animal this nerve arose by three roots. In the Gorilla and Gibbon these were L. 2, 3, 4; in the Chimpanzee and Orang, L. 1, 2, 3. Running downwards, it passed behind psoas magnus and on the surface of iliacus, to both of which it supplied branches. On entering the thigh it at once broke up into muscular and cutaneous branches. The former supplied the pectineus,¹ sartorius and the component muscles of the quadriceps extensor cruris: the latter are three important nerves, viz., middle cutaneous, internal cutaneous, and long saphenous nerves. The extent of the distribution of these cutaneous nerves varied. The middle cutaneous nerve ended in the region anterior to the knee-joint, the internal cutaneous reached the inner side of the leg, and the long saphenous in every case extended to the inner side of the foot and great toe. Moreover, in the Chimpanzee it supplied a twig to the lower half of the sartorius muscle. In its main points, therefore, this nerve closely adhered to the arrangement found in Man.

Obturator Nerve.—This nerve presented some variation in the number and position of its roots. In the Orang it commenced as high as the first lumbar nerve, but in no case did it extend lower than the fourth lumbar nerve, the usual origin being L. 2, 3, 4. It emerged from the pelvis in the usual way, and provided branches for all the members of the adductor group of muscles. In no case could a branch be traced to the pectineus muscle. In the Gibbon it seemed to entirely expend itself in the supply of muscular branches, for no cutaneous twig could be seen. In the Chimpanzee it supplied all the adductor magnus except that special ischial head to which attention has been specially directed. In this animal, moreover, the nerve was carried into immediate proximity to the knee-joint posteriorly by the expanded insertion of the adductor magnus muscle. We can therefore readily understand how this terminal twig of the nerve would remain anchored to the fibrous ligamentous structures, and so maintain its position long after the muscular fibres which carried it to that region had atrophied and disappeared. In none of the dissections could

¹ Before the Chimpanzee and Orang reached me, an examination of their hip-joints had been made. Many structures emerging from beneath Poupart's ligament had been severed, and in consequence the nerve to the pectineus was not seen.

this nerve be said to end in the synovial membrane by piercing the posterior ligament of the knee-joint.

Sacral Plexus.—In its formation the loop-like arrangement again prevailed. Only the first two sacral nerves were directly associated with the nerve-supply of the lower limb; and in fulfilling this function they were joined by the lumbo-sacral cord, the composition of which we have already seen.

Superior Gluteal Nerve.—Only in the Gibbon does this nerve arise from the lumbo-sacral cord (*vide* Kohlbrügge's figure). In the other three animals it arose by two roots, one of which is from the lumbo-sacral cord, the other from the first sacral nerve. On emerging from the pelvis it crossed the buttock, giving twigs to the usual muscles associated with it, and supplying the scansorius.

The Nerve to Pyriformis had also two roots in the Gorilla and Orang, in which it sprang from the lumbo-sacral cord and S. 1. In the Chimpanzee it arose from S. 2.

The Nerve to Obturator Internus had its usual origin from the first and second sacral nerves. It pursued its usual course, and in each case provided the twig for the gemellus superior.

The Nerve to Quadratus Femoris had its usual origin, course, and distribution as found in Man, except in the Orang, in which it descended superficial to the obturator internus and both gemelli, and ended in the muscle of its own name close to the ischial tuberosity. The twig for the inferior gemellus pursued an independent course beneath the obturator internus and superior gemellus to reach the under surface of its muscle, and it arose direct from the sacral plexus (S. 1 and S. 2).

Inferior Gluteal Nerve for the lower part of the gluteus maximus was present in each case, but in the Chimpanzee it sprang from an interlacing network of nerve-fibres, which also gave origin to the small sciatic and the trunk which supplied the hamstring muscles.

Small Sciatic Nerve.—Throughout the series this was entirely a cutaneous nerve. It took origin from the upper part of the sacral plexus by roots which sometimes, as in the case of the Chimpanzee, travelled some distance before they united. Its course lay downwards, subjacent to the lower part of the gluteus maximus muscle, at the lower border of which it entered the

thigh. When the gluteus maximus presented a hiatus between its sacral and ischial heads, as in the Orang, cutaneous branches of this nerve easily reached the skin of the buttock; and when this hiatus became lost, as in Man, their original course may explain the fact that these twigs are found piercing the lower fibres of the gluteus maximus. Leaving the buttock, the nerve travelled along the back of the thigh and the roof of the popliteal space, and terminated in relation to the skin of the upper part of the calf of the leg. Its principal named branch was the inferior pudendal nerve, which turned inwards immediately below the ischial tuberosity, and was distributed to the skin of the perineum.

Great Sciatic Nerve.—This was the principal terminal branch of the sacral plexus. It had the usual course found in Man, and at a variable distance from the knee-joint it divided into external and internal popliteal nerves. This bifurcation could easily be carried to a higher level, and a “high bifurcation” produced more or less artificially. If this be done, then we find that the external popliteal nerve springs from the lumbo-sacral cord, while the internal popliteal nerve is especially associated with the first and second sacral nerves. As a rule, the branches for the hamstring muscles arose from this nerve, either by a common trunk or as separate branches; but in the Chimpanzee these muscular twigs were found arising singly and independently from the sacral plexus. The muscles supplied in this way were the hamstrings, properly so called. In the Orang the twig for the femoral or short head of the biceps sprang from the external popliteal nerve. In addition to these branches, it is of great importance to note that it is the ischial or superficial head of the adductor magnus which received a branch from the great sciatic nerve. At first sight it would appear as if such a muscle as the adductor magnus of Man, possessing a double nerve-supply, really consisted of two separate muscles which had amalgamated; and the condition of this muscle in the Chimpanzee, where it actually consists of two distinct parts, might be taken as affording undoubted proof of this assumption. Dr Hans Gadow,¹ reasoning from the frequency of muscles

¹ Gadow, “Beiträge zur Myologie der hintern Extremität der Reptilien,” *Morph. Jahr.*, 1881.

with a double nerve-supply in lower animals, and their scarcity in mammals, concludes that double-nerve muscles show the original condition, and single nerve-muscles a subsequent development into their separate factors. Assuming this interpretation to be correct, it is certainly somewhat remarkable that in Man the brachialis anticus, pectineus, and adductor magnus muscles should so often be found in the state of double-nerve muscles, whereas in the Chimpanzee neither of these muscles presents the characteristic human condition, while in the Gibbon, Orang, and Gorilla only the adductor magnus should have two nerves. Surely, if Gadow's explanation be the correct one, we should expect to find extra muscles in the vicinity of the brachialis anticus and pectineus muscles of all the Anthropoids, and yet no such muscles are present. It seems to me, therefore, that, in consequence of their adaptability, each of the three muscles above referred to becomes amalgamated with a portion of muscle already existing in its immediate vicinity, and that this supplementary portion of muscle brings its original nerve with it, so as to produce the double-nerve appearance.

External Popliteal Nerve.—This was one of the main continuations of the great sciatic nerve from which it arose, unless by splitting this large nerve we carried the point of origin back to the lumbo-sacral cord. It had a similar course in all the animals, and ended in the substance of the peroneus longus by dividing into anterior tibial and musculo-cutaneous nerves. Its branches were fairly constant, and consisted of a few articular twigs to the knee-joint, and cutaneous branches to the back of the leg on its outer side. No communications were found between these cutaneous branches and the short saphenous nerve. In the Chimpanzee and Orang, the nerve for the short head of the biceps cruris arose from the external popliteal trunk.

Anterior Tibial Nerve.—As already mentioned, this was a terminal branch of the external popliteal nerve. In all the animals it had a similar course and distribution so far as the extensor muscles were concerned, and so far it corresponded with the arrangement found in Man, but there were points of difference in connection with its digital cutaneous branches. Thus, in the Orang it never reached the digits; in the Gorilla, it supplied cutaneous branches to contiguous sides of the index

and medius digits; while in the Chimpanzee it supplied contiguous sides of the hallux and index, and index and medius.

The foot of the Gibbon had been dissected before it reached me, and hence I was not able to examine the cutaneous nerves.

Musculo-cutaneous Nerve.—As in Man, this was a mixed nerve, destined for the supply of muscles and skin. It arose at the termination of the external popliteal nerve, and was associated with the two peronei muscles which it supplied. Thereafter, becoming a cutaneous nerve, it was distributed to the dorsum of the foot and digits, where it provided a varying number of branches. In no case did it supply the outer or inner borders of the foot, the inner border of the hallux or the outer border of the little toe. In the Orang and Gorilla it supplied all the dorsum of the foot and digits except the parts just enumerated, so that, in the Gorilla, the interval between index and medius received a double nerve-supply. In the Chimpanzee it supplied the contiguous sides of medius and annularis and of annularis and quintus: a similar arrangement of cutaneous branches was found in the Gibbon, but, for the reason already referred to, I am not in a position to make a precise statement.

Internal Popliteal Nerve.—This was in every case a larger nerve than the external popliteal. It was either a direct termination of the great sciatic nerve, or it might be traced back to its origin from the first and second sacral nerves, with an addition from the lumbo-sacral cord. In its course and distribution there was a close similarity throughout the series of animals and with the corresponding nerve of Man. It supplied both heads of the gastrocnemius, the soleus, and popliteus—the plantaris muscle being absent—and it gave off a cutaneous branch, the short or external saphenous nerve, which did not communicate with the external popliteal nerve. The distribution of this cutaneous branch was along the outer side of the foot and little toe, where, in the Orang, it formed a communication with the musculo-cutaneous nerve.

Posterior Tibial Nerve.—This was the direct continuation of the preceding nerve, the change of name occurring at the lower border of the popliteus muscle. Its course was similar to that of the corresponding nerve of Man, and it terminated close to the internal annular ligament of the ankle-joint, where it

divided into internal and external plantar branches. In its course it supplied the three deep flexors on the back of the leg, but it gave no branch to the soleus, as is usually the case in Man. It gave a cutaneous branch to the skin over the heel.

Internal Plantar Nerve.—This nerve commenced as already indicated, and ran forwards in the sole of the foot towards its inner side, supplying certain cutaneous and muscular branches.

In the Gorilla, Chimpanzee, and Orang, it provided digital branches for three and a half digits, counting from the inner side of the foot. In the Gibbon it seemed to supply contiguous sides of the index and medius and of the index and hallux.

The muscular branches supplied by this nerve were somewhat variable. In all the animals the abductor hallucis, flexor brevis digitorum, and both heads of the flexor brevis hallucis were innervated from this source. In the Gorilla it supplied the innermost lumbrical muscle, in the Orang and Gibbon the two inner lumbricales, and in the Chimpanzee the three inner lumbricales. Finally, in the Chimpanzee it likewise sent twigs to the adductor obliquus hallucis, a muscle which, in the same animal, also received branches from the deep division of the external plantar nerve.

External Plantar Nerve.—This was the remaining terminal branch of the posterior tibial nerve. It crossed outwards in the sole of the foot as in Man, and supplied all the remaining cutaneous and muscular branches which were required to complete the innervation of the sole of the foot. From its main trunk it supplied the abductor minimi digiti and the accessorius when the latter was present. Its superficial division completed the cutaneous supply of the digits, *i.e.*, the outer one and a half digits of the Gorilla, Chimpanzee, and Orang, and the contiguous sides of the medius and annularis, and of the annularis and quintus of the Gibbon. From the superficial division there also sprang muscular branches for the flexor brevis minimi digiti, opponens minimi digiti, and the muscles in the outermost interosseous space. The deep division of the nerve turned inwards across the sole of the foot subjacent to the adductor stratum of muscle, and sent twigs to the whole of this stratum, the remaining interossei and the remaining lumbrical muscles. In the Chimpanzee, as already noted, the

adductor obliquus hallucis also received branches from the internal plantar nerve.

From these descriptions and comparisons, I think that intelligent explanations have been adduced for many of the apparent anomalies of the nerve-supply of the muscles in the extremities of Man; and while being quite convinced of the importance of regarding the nerve-supply of a muscle in the light of a key to its probable homology, still I think that we have a sound foundation for believing that this relationship is not absolute, but may be subject to variation. As an illustration of this variation, I may again refer to the pronator quadratus of the Gibbon, in which my dissection showed a nerve-supply from the posterior interosseous nerve; for, in spite of this somewhat erratic source of nerve-supply, there can be no doubt that the muscle was the pronator quadratus. On the other hand, I believe that the hypothesis of Gegenbaur and Ruge is well supported by many of the facts detailed in the foregoing pages. Again, from my dissections, it seems to me to be far more probable that such a muscle as the brachialis anticus of Man derives its double nerve-supply by reason of the amalgamation of muscular fibres originally associated with two distinct sources of nerve-supply, rather than that it shows a condition in which the muscle has not yet split into its two ultimate factors; for even in the Gibbon, in which there is a considerable amount of fusion among the muscles of the upper arm, there is no double nerve-supply to the brachialis anticus.

EXPLANATION OF PLATE IX.

Fig. 1. Plantar aspect of the foot of the Gibbon. Fig. 2. The same of the Orang. Fig. 3. The same of the Chimpanzee. Fig. 4. The same of the Gorilla.

Ab. H., Abductor Hallucis. *F. b. h. (i.)*, Flexor brevis hallucis (inner head). *F. b. h. (o.)*, Flexor brevis hallucis (outer head). *F. l. h.*, Flexor longus hallucis. *Ad. H. ob.*, Adductor hallucis obliquus. *Ad. H. tr.*, Adductor hallucis transversus. *F. B. dig.*, Flexor brevis digitorum. *Ab. m. d.*, Abductor minimi digiti. *F. b. m. d.*, Flexor brevis minimi digiti. *P. L.*, Tendon of peroneus longus. *C.*, Contrahens.

Fig. 5. Dorsal interosseous muscles of the foot of the Gibbon. Fig. 6. The same of the Orang. Fig. 7. The same of the Gorilla. Fig. 8. The same of the Chimpanzee.

d¹, d², d³, d⁴, First, second, third, and fourth dorsal interosseous muscles. *p¹* in fig. 7, First plantar interosseous muscle.

THE CERÉBRAL HEMISPHERES OF *ORNITHORYNCHUS PARADOXUS*. By Professor Sir WILLIAM TURNER, M.B., D.C.L., LL.D., F.R.S.

(Communicated to the Anatomical Society, Feb. 20, 1892.)

AT the time when I was engaged in the preparation of my address on the "Convolutions of the Brain," for the Anatomical Section of the International Medical Congress in Berlin,¹ I had not a satisfactory specimen of the brain of *Ornithorynchus*. The two examples then in my possession had been removed from crania in which they had been imperfectly preserved. I was unable, therefore, to give a figure of the hemispheres, or to state more in the way of description than that each hemisphere had two fundamental limiting-fissures, a rhinal and a hippocampal, which formed the limits of the rhinencephalon, and that, in the concavity of the hippocampal fissure, a gyrus dentatus was situated; also that the surface of the pallium was apparently without fissures, though indented with shallow vascular furrows. On inquiry at the Museum of the Royal College of Surgeons of England, and at the Museum of the University of Oxford, I found that neither of these important collections contained a specimen.

Meckel had given figures of the brain in his well-known treatise, *Ornithorynchi Paradoxi Descriptio Anatomica*,² and Owen had also published figures,³ two of which were apparently reproductions of the corresponding figures in Meckel's treatise. But as the cranial surface of the hemispheres had been represented by these anatomists with the pia mater and its blood-vessels still enveloping it, I was unable to make a proper comparison of the brain of *Ornithorynchus* with that of *Echidna*. I applied, therefore, to my friend Professor Anderson Stuart, of the University of Sydney, and asked him to obtain for me, if

¹ This address was published in the *Jour. of Anat. and Phys.*, October 1890, vol. xxv., and in the *Verhandl. des Intern. Med. Congress*, Band ii., specieller Theil, p. 8, 1891.

² Leipsic, 1826, Tabula vii.

³ *Anatomy of Vertebrates*, vol. 3, pp. 84, 101.

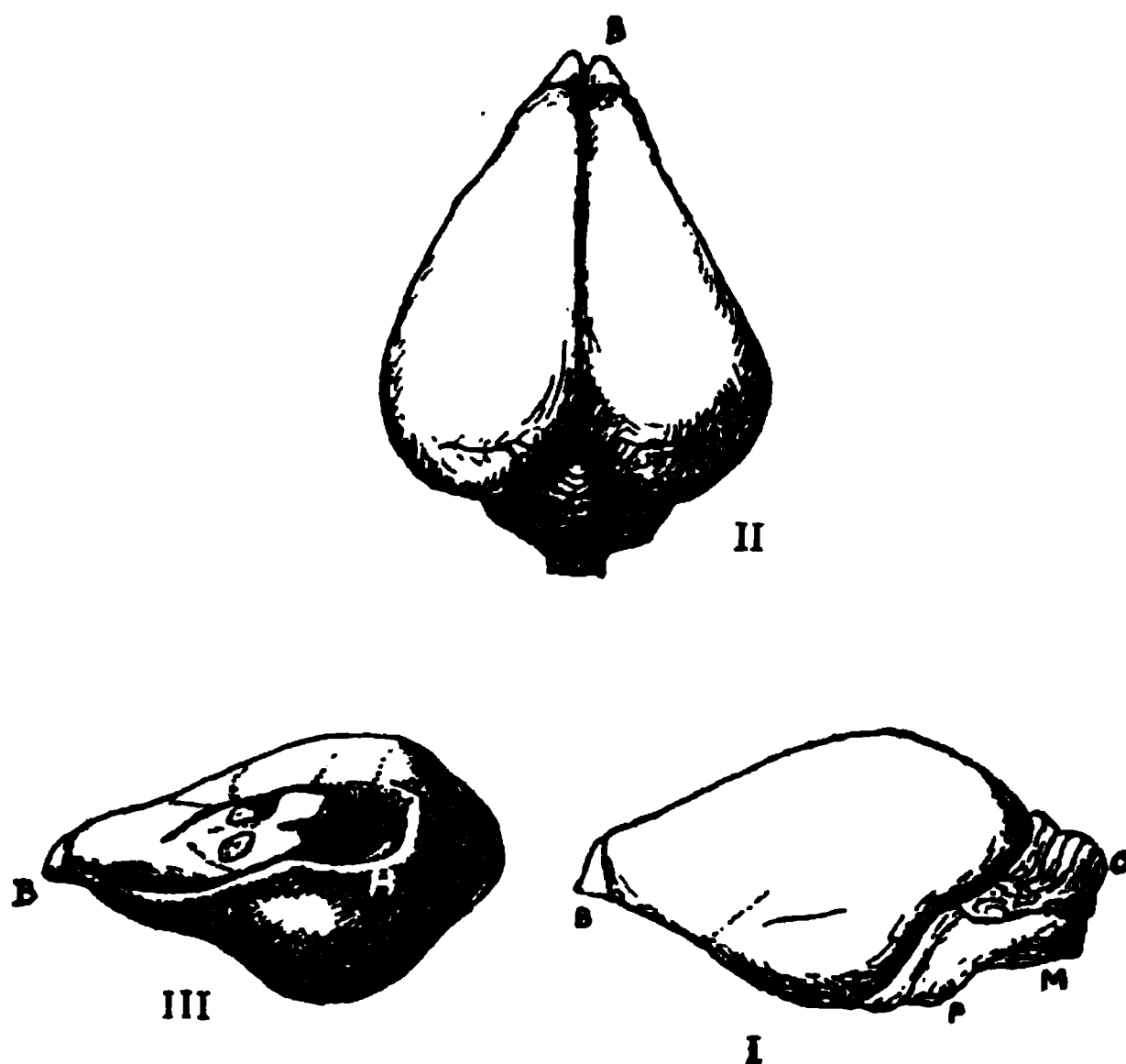
possible, a properly preserved brain of this animal. With his customary courtesy he complied with my request, and presented to me in November last a brain preserved in spirit.

The brain was covered by the pia mater, and the ramifications of the veins, filled with coagulated blood, in the membrane covering the surface of the hemispheres, were observed to present an appearance not unlike Meckel's figures. When the pia mater was stripped off, the cortex was seen to be indented by lines running from before backwards along the course of the principal vessels, but the indentations did not amount to fissures.

The hemisphere consisted of both rhinencephalon and pallium. The rhinencephalon was for the most part situated, as Meckel figures it, on the under surface of the hemisphere, and the demarcation between it and the pallium was shown by a distinct ectorhinal fissure on its outer border and an endorhinal fissure on its inner border, the latter of which separated it from the area termed the quadrilateral space. The bulb of the rhinencephalon projected for only a short distance in front of the pallium; it measured 3 mm. in antero-posterior, 2 mm. in breadth, and 5 mm. in vertical diameter. The crus or peduncle was a narrow band about 1 mm. in transverse diameter at its widest part. It could only be seen on the under surface of the hemisphere, and when the cerebellum was removed it could be traced backwards into the lobus hippocampi, with which it was continuous. The vallecule or Sylvian fossa was so faintly marked that the plane of separation between the crus and the lobus was scarcely defined. The lobus elongated from before backwards had a breadth of 2 mm., and was differentiated on its outer and posterior aspect by the ectorhinal fissure, and on its inner and anterior aspect by the fissura hippocampi. The part of the cerebral cortex into which the lobus was continued superiorly, and which was bounded by the same fissures as the lobus, may be regarded as representing the gyrus hippocampi in the higher brains.

In their general form the hemispheres were ovoid when seen from the vertex, with the narrow end forwards. They diverged somewhat from each other posteriorly, and the middle of the tentorial surface of the cerebellum, which was elevated into a

ridge, filled up the interval between them, whilst laterally the same surface of the cerebellum was in close relation to the under surface of the hinder part of the cerebrum. No portion of the optic lobes was visible so long as the hemispheres were undisturbed. The cranial surface of the pallium was smooth, though with the vascular indentations above referred to. In addition, a linear mark, not amounting to a fissure, started from near the middle of the ectorhinal fissure, and passed obliquely upwards and backwards on the cranial surface of the pallium. It had the position and direction of the Sylvian fissure, but was so faint that it was possibly only the mark pro-



EXPLANATION OF FIGURE.—I. and II., vertex and profile view of brain of Ornithorhynchus; III., the mesial and inferior surfaces of the right hemisphere. *B*, bulbus; *H*, lobus hippocampi; *C*, cerebellum; *M*, medulla oblongata; *P*, pons; *D*, gyrus dentatus. Drawn by H. G. Melville, M.B.

duced by a small blood-vessel. Immediately behind this mark was a somewhat deeper indentation in the left hemisphere, but not in the right, which extended for 3 mm. in an antero-posterior direction. A similar shallow depression ran for 5 mm. transversely outwards from the posterior border of each hemisphere.

The mesial surface of the hemisphere was exposed by an antero-posterior section, and the optic thalamus was removed. The anterior commissure and the rudimentary corpus callosum transversely divided were seen at the surface of the section, and behind these was the hippocampus. A shallow antero-posterior fissure 6 mm. long was observed on the mesial surface of the pallium in front of and above the divided corpus callosum. It might possibly be the splenial fissure, and the slender band of the pallium between it and the corpus callosum would thus represent a rudimentary callosal convolution. This fissure seemed at first as if it ended behind in the fissure which lodged the velum interpositum; but when the parts were drawn asunder, it was seen to be separated from that fissure by a narrow band continuous with the rudimentary callosal convolution. Shallow vascular indentations ran from this fissure to the upper margin of the hemisphere. A gyrus dentatus, which was, however, smooth on the surface, was situated in front of the hippocampal fissure. At its upper part it was 1.5 mm. in breadth and close to the plane of the mesial surface; but lower down it receded from that plane and was attenuated into a narrow edge.

A comparison was then made between the brain of *Ornithorhynchus* and that of the *Echidna* figured in my address on the convolutions.¹ As will be seen from the accompanying table of measurements,² the brain of *Echidna* is considerably larger than that of *Ornithorhynchus*.

	<i>Ornithorhynchus</i> .	<i>Echidna</i> .
Length of pallium, . . .	29	39
Height of „ . . .	18	27
Breadth of cerebrum, . . .	26	40
Projection of rhinencephalon in front of pallium, }	3	10
Length of cerebellum, . . .	11	18
Breadth of „ . . .	15	23

All the parts of the rhinencephalon are more fully developed in *Echidna*. The bulb, which measures 15 mm. in length by 10 in breadth, is both longer and wider, and projects considerably

¹ *Op. cit.*, figures 8 and 9, *Journal of Anat. and Phys.*, vol. xxv.

² It should be noted that all the measurements recorded in this paper were on brains hardened in spirit.

further in front of the pallium. The crus is 8 mm. in width, and both it and the ectorhinal fissure are visible on the side of the hemisphere when viewed in profile, and are not limited to the under surface as in *Ornithorynchus*. A portion of the lobus hippocampi also projects below the pallium, and is seen in the side view of the brain of *Echidna*, in which it has a breadth of 8 mm. The cranial surface of the pallium is distinctly convoluted in *Echidna*, but in *Ornithorynchus* it is only marked by vascular furrows, with the addition of the slight indentations referred to in the description. *Echidna* possesses a definite splenial fissure, separated from the corpus callosum by a relatively large callosal convolution, and has some additional fissures on the mesial surface. In *Echidna* the gyrus dentatus is relatively larger and is distinctly denticulated. The convolution into which the lobus hippocampi is prolonged superiorly, and which apparently represents the gyrus hippocampi, is more massive in *Echidna* than in *Ornithorynchus*.

From the comparison above given, it is obvious that the rhinencephalon or olfactory part of the brain is much larger and more highly developed in *Echidna* than in *Ornithorynchus*. The pallial part is also on a larger and more complicated plan. It possesses much greater bulk, and its cortex is arranged in definite convolutions. But the cerebellum also is a much larger organ, its surface is more minutely divided by fissures, and the bud-like processes, which form the lateral lobes or hemispheres, though small when compared with the higher brains, are more distinctly differentiated in *Echidna*. The conclusion therefore to which one has arrived is, that *Echidna* possesses a more highly organised brain than is found in *Ornithorynchus*.

**A FEW APPLICATIONS OF A PHYSICAL THEOREM
TO MEMBRANES IN THE HUMAN BODY IN A
STATE OF TENSION.¹ By ROBERT H. WOODS, M.B.
(Dub.), *Throat Surgeon to the Richmond Hospital, De-
monstrator of Anatomy in Trinity College, Dublin, &c.***

It will first be necessary to state the theorem which I intend to apply.

On a section of a cylinder of radius r containing fluid under a pressure of P lbs. per square inch let us take two diametrically opposite points A B and find the tensions per inch run of the cylinder at these points.

The total pressure acting on the semi-circumference of a ring an inch wide will be $P\pi r$. But the stress or tension at A and B is not represented by this total pressure, but by the sum of the resolved parts of its components in a direction at right angles to the diameter AB . The sum of these components is equal to the pressure on an area formed by the diameter of the cylinder multiplied by unity or $= 2Pr$, but since an equal share is borne by A and B , the tension or stress at either point is :

$$T \propto Pr \text{ or } P \propto \frac{T}{r}$$

This is for the simple case of a surface curved circularly in one direction. If the surface be curved in a direction at right angles to this, the second radius of curvature being r_1 , we have :—

$$P \propto T \left(\frac{1}{r} + \frac{1}{r_1} \right) \quad . \quad . \quad . \quad . \quad . \quad (a)$$

From whence it is seen that the tension of a membrane enclosing a fluid under a given pressure is not a fixed quantity, but is greater the greater the radii of curvature of the membrane. The truth of this may be put to a practical test by distending a large and a small bag of the same material with a fluid, the pressure of which is gradually raised. It will always

¹ A paper read before the Royal Academy of Medicine in Ireland on January 15, 1892.

be found that the larger of the two will be the first to burst, while the smaller will remain intact under a very much higher pressure.

If, now, we apply this to the heart, we see that the muscle of the heart in the distended state of the organ must, on account of the larger size of its cavity, and necessarily greater radii of its walls, make a much greater effort at contraction, in order, by means of the tension of the walls, to raise the contained blood to the pressure of that in the aorta, than when the ventricle is more contracted, as *e.g.* at the middle or end of systole.

Again, the thinner the heart-wall is,—that is to say, the fewer muscle fibres there are on cross section,—the more will each fibre have to exert itself to bring about a given tension; and when it is considered that the wall of the heart is thinnest when the organ is most dilated, it will be seen that this must form another and not unimportant factor in contributing to the difficulty of commencing systole.

Let us now go a little more accurately into these points.

If we apply the fact that the surface area of a sphere varies as the square of its radius, and bear in mind that the total number of muscle-fibres is a constant quantity, we see that the number of muscle-fibres per unit of area on the heart-wall varies inversely as the square of the radius,—that is, supposing for a moment the heart to be a sphere. Hence, for a given exertion of muscle-fibre the tension will vary inversely, as the square of the radius, or

$$T \propto \frac{1}{r^2}.$$

Still regarding the heart as a sphere, the formula (a) above,

$$P \propto T\left(\frac{1}{r} + \frac{1}{r_1}\right)$$

now becomes

$$P \propto \frac{2T}{r}$$

But $T \propto \frac{1}{r^2}$ as just shown, therefore

$$P \propto \frac{1}{r^3}.$$

Thus we arrive at the somewhat startling result that the pressure varies inversely as the cube of the radius when the exertion of each individual fibre is taken as constant, or if we regard the pressure as constant, the exertion or pull of each muscle fibre must vary as the cube of the radius of curvature. So that if we suppose the heart to be in two conditions, the first condition having a certain diameter, and the second a diameter twice as great, the heart will have to exert itself eight times as much in the second position as in the first, in order that the same pressure may be exerted on the contained blood.

This enormous disadvantage under which the heart in the beginning of systole labours, is surely more than sufficient to demand extra mechanism to overcome it; and it now remains to be considered how it had best be done.

The difficulty could easily be disposed of by heaping on layers of muscular fibres outside those which were barely sufficient in the contracted condition; but this would be attended by the disadvantage of more required room, and of having the extra fibres acting at a time when they were wholly unnecessary, *i.e.*, towards the middle and end of systole, which would not be in accordance with the principle of least action enunciated by Dr Haughton in his great work on animal mechanics, and shown by him to be universal in the animal economy. Some cheaper way must, then, be sought. It is found in the *columnæ carneæ*, and, as I hope to show, in the *musculi papillares* also. These muscles, which stretch across the cavity of the heart from wall to wall, exert their influence more immediately on the blood by pulling more directly on the ventricular wall, and consequently are more efficient than if they lay on the outside of the wall itself. On account also of the rapidity with which their origins and insertions approximate the one to the other, their force must diminish towards the middle, and fade away towards the end of systole; thus compensating in a singularly beautiful way for the disadvantage at which the heart-wall is placed at the commencement of its contraction.

It may be objected that placing muscles inside the heart cavity would necessitate its enlargement for the purpose of making room for them. But a little consideration will show

this is not the case. For suppose the heart a sac with smooth walls, it would be quite impossible for it to contract so as to obliterate or even almost obliterate its cavity when expelling blood under considerable pressure, owing to the difficulty of approximating the origins and insertions of the fibres, especially of the innermost layers, so that the only difference their presence makes consists in diminishing the quantity of residual blood in the heart.

The urinary bladder is no exception to this, but rather an illustration. For the last quantity of urine is got rid of not by the exertion of the bladder wall, but by the *vis a tergo* of the abdominal muscles and the pumping of the accelerator urinæ muscle, aided to some extent by gravity. Here, too, the resistance to be overcome is negligible, being nothing more than that offered by the friction of the urine against the walls of the urethra. The bladder, furthermore, as shown by frozen sections, is in the contracted condition not spherical, but somewhat T-shaped, which it could not be if its walls were in contraction at the end of the act of micturition.

The muscoli papillares are usually considered as having only to do with controlling the mitral and tricuspid valves. But they must also aid in expelling the blood. For the exertion necessary to prevent the valves from flapping back into the auricles must also react on the ventricular wall and help it in its effort at contraction. They must then be looked upon as having the double function of controllers of the valves and true working muscles of the contracting heart itself.

Another and a very interesting example of similar, though less complete, prominence or ridging of muscular fibres on the inside of a contractile sac, for the purpose of exerting greater pressure on the contained fluid, is exhibited as a pathological condition in the urinary bladder in cases where the outflow of urine is gradually resisted, as in the bladder of enlarged prostate. Here the innermost fibres raise themselves up from the wall hypertrophy, and by their peculiar disposition increase their efficiency. I am inclined to regard this as an attempt on the part of the bladder to simulate the construction of the heart by providing, when the necessity arises, its own columnæ carnæ; and if this be so, it cannot fail to strike one as being an

unusually elegant example of the wonderful resources of Nature when combating disease.

In cases of valve disease the heart becomes dilated to allow for regurgitation, in order that the quantity of blood thrown into the aorta may as nearly as possible be kept normal, and so the blood-pressure kept up. There is, however, reason to believe that in spite of this the blood-pressure in most cases falls a little. Concomitant with dilatation we have hypertrophy. What is the cause of this hypertrophy, especially if the blood-pressure be lower than before? The reason is because the tension required in the ventricular wall to raise the blood, even to a lower pressure, is greater when the heart is pathologically dilated, and so its wall-curvature more gradual, than when of normal size, and the curvature sharper.

It is a well-known fact that the apex of the heart is its thinnest part. The reason is simple. It is because here the curvatures of the wall are sharpest, and, as above shown, the tension required to resist or cause a given pressure in the ventricle will be less than where the curvature is more gradual. The same reason explains why, when the heart bursts, as in buffer accidents, without any part having been specially diseased, the thinnest part is not always chosen as the seat for rupture.

This question of tension in the walls of a sac containing fluid under pressure explains the absence from fusiform aneurysms and varicose veins of any effort to heal spontaneously; for the more the vessels dilate, the higher the tension in their walls rises, and the more incapable they are of contracting to diminish their calibre.

In fact, when we take into consideration the comparatively great radii of curvature of the sac of an aneurysm, and the consequently great height of the tension in its walls which the blood-pressure in its interior must give rise to, and bear in mind the diseased condition of its walls, we cannot help wondering that they do not more frequently burst than they are known to do.

Let us now for a moment regard the uterus in labour, and I think we shall see the real reason why letting a quantity of *liquor amnii* flow away precipitates parturition. It is because

this act diminishes the capacity, and so the radii of curvature of the uterine walls, and thus enables the organ to exert a greater pressure on its contents than in its former more dilated condition.

The "atony" of the uterus, where the quantity of *liquor amnii* is excessive, is, I believe, to be explained in the same way—that is, the too great curvature of the walls of the uterus,—and is not to be attributed to the overstretching of the muscular fibres; for it is not easy to conceive that the *liquor amnii* can increase so rapidly as not to give time for the muscular fibres to adapt themselves to the change. Whether this reason is the only one I am not prepared to say, but that it is a very important one no one can deny.

It will be admitted that the thickness of the heart at any place bears a direct proportion to the relative tension at that place. Hence it follows that in the equation (a) above, we ought to be able to substitute t the thickness of the walls, for T the tension. The equation will then be

$$P \propto t \left(\frac{1}{r_1} + \frac{1}{r} \right)$$

or if the pressure be constant, $t \left(\frac{1}{r_1} + \frac{1}{r} \right)$ will also be constant; or, in general terms, the thickness varies as the radii of curvature.

I have experimentally put this to the test in the following way. Some hearts were obtained, and the auricles having been ligatured, the aortic and pulmonary valves were destroyed, and glass tubes tied into their orifices. The ventricles were then dilated with spirit under a head of about 12 in., and so left until they were hardened. Points on the ventricular surface were then selected and marked with labelled pins, and the curvatures in two directions at right angles to one another estimated for each point. The heart was finally cut, and the various thicknesses at the marked points measured.

One heart was an adult's, another a child's about twelve months old. A third, adult heart, I compressed so as, as far as possible, to imitate the contracted condition of the organ, and see if here the relationship held; but in this case the measurements of the curvature were not so reliable, as it

was difficult to make sure that the walls were uniformly compressed, and indeed I have reason to believe that I did not very well succeed.

I have tabulated the results (see below), and I think they show the theorem to be correct within the limits of experimental inaccuracy. It will readily be understood that these measurements are not very easy to take; for in the one case the curvature sometimes changes so rapidly that only a small line can be taken as a segment of a circle, and in the other case the attachments of the columnæ carneæ do not always leave it clear at exactly what point the true heart-wall stops and the columnæ themselves may be said to begin.

On the whole, however, the results more than realised my anticipations, and may, I think, be taken as proving the point.

There were two points taken on the left ventricle of the adult heart—one near the anterior, and the other near the posterior interventricular groove; but here the formula did not hold good, and the results were so much at variance with the rest that I had to omit them. This is confirmatory of the proposition; for it shows that where the conditions were disturbed by the proximity of the interventricular septum, there, as might have been anticipated, the relation between curvatures and thickness did not hold.

Another point of interest is brought about by these tables, viz., that the pressure in the left heart is about three and a half times as great as in the right in the child's case, and about six and a half times as great in the case of the adult.

This latter result, I have since found out, corresponds almost exactly with the experimental observations of Knoll on the rabbit. His exact proportion was 1:6·8. The proportion in the child's case is, I have reason to believe, not correct, as the ventricles were not in a similar condition.

There is good reason to believe that the pressure in the aorta of an adult is a little over 9 feet of water. This being so, the pressure in the pulmonary artery would be 17 inches.

This accounts for the fact that the left ventricle is more rounded on section, the mean curvature of its walls sharper, and their thickness greater than the right.

The left ventricle is the model of what a ventricle ought to

be. The right could, I think, be improved upon. The work could be more cheaply done by having another (free) heart, consisting of a simple auricle and ventricle, instead of having one ventricle tacked on to the outside of another. For this would admit of the wall-curvature being sharper, and so the required tension smaller. Whether the exigencies of space and the shape of the organs would admit of such an arrangement I can't say, for of course these elements, and perhaps others too, would enter into any plan of remodelling.

The thickness of the walls of the systemic arteries diminishes the further we go away from the heart, but more rapidly than the blood-pressure, the reason being that the bore also diminishes, and so the radius of curvature; and hence the required tension in the arterial walls diminishes proportionately.

ADULT HEART (*normal*).

Under pressure 12 in Right Ventricle.

Label of point chosen.	r mm.	r_1 mm.	t mm.	$t\left(\frac{1}{r} + \frac{1}{r_1}\right)$
z_1	60	60	1.5	.050
c_2	65	80	2.0	.055
d_2	32	75	1.25	.055
a_2	75	90	2.2	.054
e_2	30	45	1.0	.055
f_2	55	90	2.0	.058
	—	—	—	—
				.0545 = average.

Left Ventricle.

p_1	36	60	8.0	.35
z	32	80	8.5	.37
x_1	70	36	9.5	.39
r_1	30	80	8.5	.38
o_1	28	60	7.0	.36
s_1	70	40	8.5	.33
m_1	80	40	10.0	.37
w_1	32	80	8.5	.34
f_1	55	16	5.0	.40
t_1	70	24	6.0	.33
v_1	24	70	6.5	.36
n_1	60	24	6.0	.35
	—	—	—	—
				.36 = average.

CHILD'S HEART (*normal*).

Under pressure 12 in Right Ventricle.

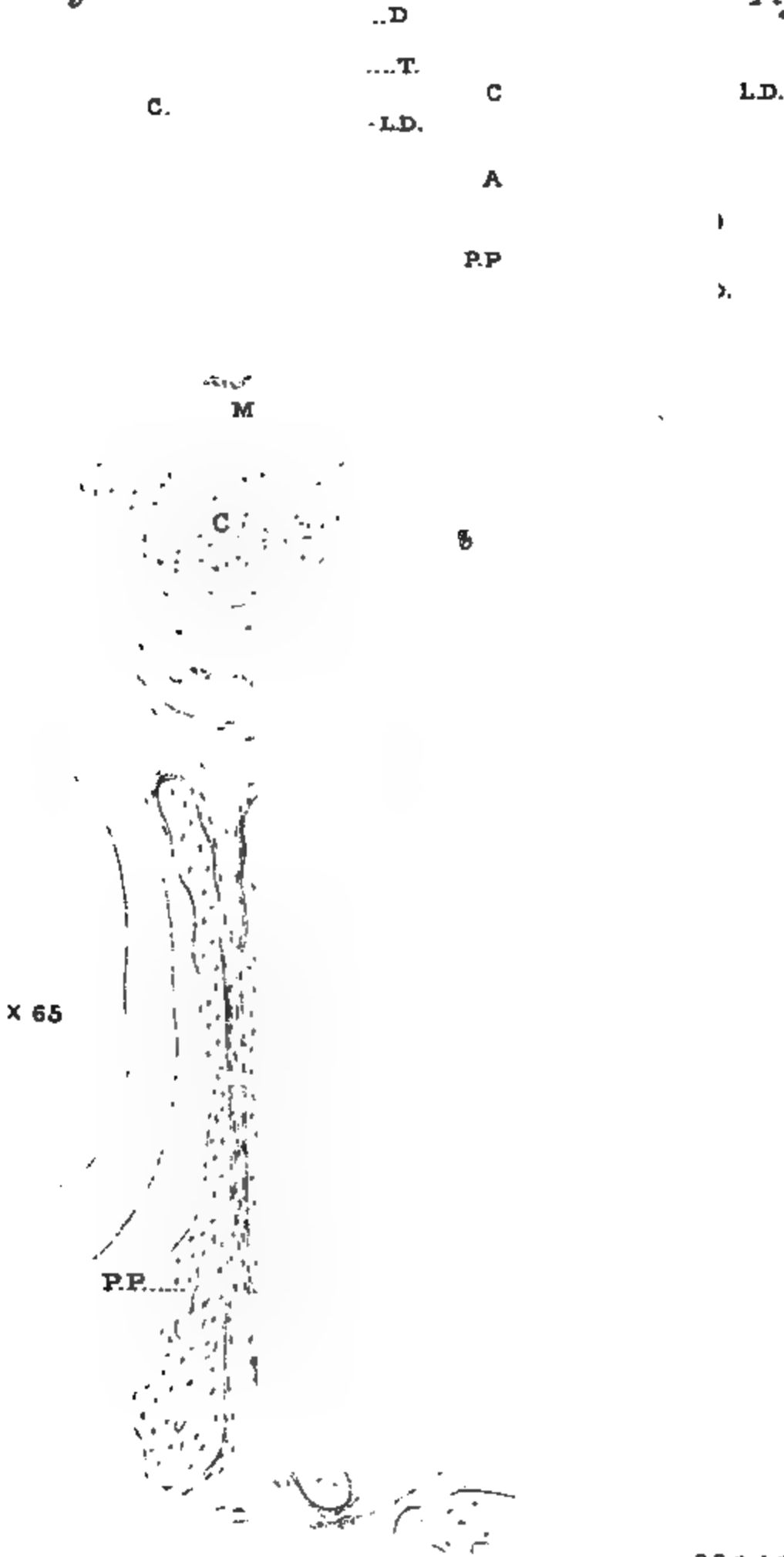
Label of point chosen.	<i>r</i> mm.	<i>r</i> ₁ mm.	<i>t</i> mm.	$t\left(\frac{1}{r} + \frac{1}{r_1}\right)$
<i>e</i> ₁	50	22	2·2	·14
<i>c</i> ₁	40	20	2·0	·15
<i>h</i> ₁	18	55	2·5	·18
<i>d</i> ₁	80	30	3·0	·14
<i>i</i> ₁	60	20	2·0	·13
<i>b</i> ₁	55	16	2·5	·20
<i>a</i> ₁	80	24	3·0	·16
<i>l</i> ₁	10	40	1·2	·15
<i>g</i> ₁	6	18	·7	·15
	—	—	—	—
				·166 = average.

Left Ventricle.

<i>o</i>	18	22	6·0	·60
<i>n</i>	24	16	5·5	·57
<i>v</i>	38	22	7·5	·54
<i>l</i>	14	34	5·5	·56
<i>t</i>	50	14	6·4	·58
<i>q</i>	20	55	7·0	·50
<i>s</i>	12	36	5·25	·61
<i>p</i>	10	65	5·0	·58
<i>r</i>	12	22	4·5	·57
<i>w</i>	22	10	4·0	·58
<i>y</i>	9	18	3·0	·50
	—	—	—	—
				·56 = average.

Fig. 1.

Fig. 2.



F. Roth, Lith. Edin.

ON THE ORGAN OF JACOBSON IN THE KANGAROO
AND ROCK WALLABY (*MACROPUS GIGANTEUS*
AND PETROGALE PENICILLATA).¹ By JOHNSON
SYMINGTON, M.D., F.R.S.E., *Lecturer on Anatomy, Minto*
House, Edinburgh. (PLATE X.)

(Read before the Scottish Microscopical Society, Dec. 1891.)

THE structure of the organ of Jacobson in the Marsupialia is a point of some morphological interest in connection with the relation of these animals to the Prototheria on the one hand, and the Eutheria on the other. It has been recently shown by Professor W. N. Parker² that the *Echidna* possesses a highly-developed Jacobson's organ, and I have found³ that this is also the case in the *Ornithorhynchus*. The structure of this organ in the Eutheria division of the mammalia has been investigated by Gratiolet, Balogh, Herzfeld, Schwink, Gegenbaur, Kölliker, Klein, and others, and in none of these animals is the organ nearly as highly developed as in the Monotremes. Being unable to find any reference to its condition in the Marsupialia, and having several pouch specimens of the great kangaroo and rock wallaby in my possession, I decided to examine them for this organ. The specimens used were (a) the head of a *Macropus giganteus*; total length of animal measured from the snout round the top of the head and along the back of the trunk to the root of the tail was 12·7 cm.; length of head, 3 cm. (b) The head of another macropus of larger size; the distance from snout to tail, measured as above, being 15·2 cm., and its head 3·7 cm. (c) The head of *Petrogale penicillata*; length from snout to root of tail, 8·5 cm.; length of head, 2 cm.

All the specimens were embedded in paraffin, and the head divided into a series of coronal sections. The condition of the organ was practically identical in all the three specimens. In

¹ From the Embryological Laboratory, University of Edinburgh.

² "Exhibition and Remarks upon some young specimens of *Echidna aculeata*," at British Association Meeting, 1891. See *Nature*, 17th September 1891.

³ "On the Nose, the Organ of Jacobson, and the Dumb-bell-shaped Bone in the *Ornithorhynchus*," read at Meeting of Zoological Society of London 17th November 1891, and to be published in next number of its Proceedings.

almost all, if not all, mammals which possess an organ of Jacobson, this is provided with a more or less complete cartilaginous investment. This cartilage has a comparatively simple arrangement in my specimens. About 1 mm. in front of the organ of Jacobson and Stenson's duct the cartilaginous septum nasi divides at its dorsal end into two plates which curve round their corresponding nasal cavities, and end on the inner side of the floor of the nose just external to the nasal septum, to the cartilage of which they are united by perichondrium (see fig. 1, Plate X.). Following the serial sections from this point backwards, we observe that the floor of the nose becomes depressed, and the cartilage in the floor undergoes a corresponding depression, so that its upper surface becomes distinctly concave. This longitudinal groove in the nasal floor corresponds to what Dr Klein described in the guinea-pig as the lower nasal furrow. A few sections further back we find the floor of the nose perforated by the naso-palatine or Stenson's duct, and here the curved plate of cartilage above described is separated into an inner and an outer portion (see fig. 2, Plate X.). The inner one becomes the cartilage of Jacobson's organ. At first this is a plate flattened from within outwards, but as soon as it comes into relation with Jacobson's organ it acquires a U-shaped form. The limbs of the U are united below, and the inner limb is longer than the outer (see fig. 3, Plate X.).

In no part of its extent does the cartilage form a complete ring. Posteriorly it first loses its outer limb, and finally ends a little in front of the posterior end of Jacobson's organ. In the great part of its extent the cartilage of Jacobson's organ lies in the nasal septum external to the palatine process of the pre-maxillary bone, and below the level of the septal nasal cartilage (see fig. 3). Near its posterior end, however, it is found on a level with the lower part of the septal cartilage, but separated from it by the vomer.

In 1860 Dr C. Balogh¹ gave an elaborate description of the cartilage of Jacobson's organ in the sheep, and more recently Dr E. Klein,² in several papers, has described with great care

¹ "Das Jacobsonsche Organ des Schafes," *Sitzungsab. d. k. Akad. d. Wiss. Wien.*, Bd. 42. 1860.

² (a) "Contributions to the Minute Anatomy of the Nasal Mucous Membrane,"

this cartilage in the guinea-pig, rabbit, and dog. In each of these animals it presents certain individual peculiarities, but in all of them it has essentially the same general form as in the kangaroo, viz., a curved plate of cartilage situated in the lower part of the nasal septum, and forming a partial investment for Jacobson's organ. In the guinea-pig and rabbit it forms, for a short distance, a complete tube; but this does not appear to be the case in the sheep or dog. In the rabbit Dr Klein described the cartilage of Jacobson's organ as extending as far as or even beyond the organ itself, while in the guinea-pig a considerable part of the organ is not provided with any cartilage.

The organ of Jacobson is a simple epithelial tube, the lumen of which communicates in front with the naso-palatine foramen, and ends blindly behind. On transverse vertical section the organ is found to be flattened from side to side, and its outer wall pushed slightly inwards, so that it may be described as somewhat kidney-shaped. The outer epithelial wall of the tube closely resembles that lining the respiratory part of the nose, consisting of columnar cells mixed with a few goblet cells. The columnar cells are probably ciliated, although in my specimens the cilia were with difficulty recognised. The inner epithelial wall is between two and three times thicker than the outer, and its structure closely corresponds to that of the olfactory region of the nose. Beneath the superficial columnar cells there are numerous round or oval cells with well-marked nuclei. These are the sensory cells. External to the epithelium there is a layer of connective tissue containing a few dilated capillaries, and towards the posterior part of the organ some serous glands, the ducts of which open into the lumen of the organ.

From the above description it will be evident that the organ of Jacobson in the kangaroo closely resembles in its form and structure the same organ in the majority of the Eutheria in which it has been investigated. Thus Dr P. Herzfeld¹ has

Quar. Jour. Micros. Science, January 1881. (b) "A further Contribution to the Minute Anatomy of the Organ of Jacobson in the Guinea-pig," *Quar. Jour. Micros. Science*, April 1881. (c) "The Organ of Jacobson in the Rabbit," *Quar. Jour. Micros. Science*, October 1881. (d) "The Organ of Jacobson in the Dog," *Quar. Jour. Micros. Science*, July 1882.

¹ "Ueber das Jacobson's Organ des Menschen und der Säugethiere," *Zool. Jahrb. Abth. f. Anat. u. Ontog.*, Bd. 111.

shown that the typical arrangement in these animals is for the duct of Jacobson's organ to open anteriorly into the naso-palatine foramen. Such is the case in the sheep, cow, pig, dog, cat, mole, &c. Then, again, the microscopic structure of the organ in the kangaroo is practically identical with that of these animals.

A comparison of the organ of Jacobson in the Kangaroo with that in the Monotremes shows at once very marked differences. Thus in the *Ornithorhynchus* the cartilage, in the greater part of its extent, forms a complete tube, from which there passes inwards a well-developed turbinated process. No indications of such a process have as yet been found in any of the *Metatheria* or *Eutheria*. Then, again, in the *Ornithorhynchus* the organ extends forwards as well as backwards beyond its opening into the naso-palatine foramen, while in the other mammals the opening, which may be either into the naso-palatine foramen or directly into the nose, always represents the anterior extremity of the organ. Lastly, the organ is much larger in the *Ornithorhynchus* than in the Kangaroo.

EXPLANATION OF PLATE X.

All the Figures are drawn with a Camera.

Fig. 1. Coronal section of nose in front of Stenson's duct. *c*, Cartilage in septum nasi ; *d*, Cartilage in lateral wall of nose ; *e*, Cartilage in floor of nose ; *t*, Turbinal cartilage ; *n.c.*, Nasal cavity ; *p.p.*, Palatine process of premaxillary bone ; *l.d.*, Naso-lacrymal duct ; *m*, Cavity of mouth.

Fig. 2. *o*, Opening of duct of Jacobson's organ : *s.d.*, Stenson's duct ; *a*, Cartilage of Jacobson's organ ; other letters as in fig. 1.

Fig. 3. *i*, Inner wall of Jacobson's organ ; *o*, Outer wall ; *j*, Cavity ; *n.e.*, Epithelium on inner wall of nasal cavity ; other letters as in fig. 1.

ON THE EFFECT OF CERTAIN DRUGS ON THE
REFLEX EXCITABILITY OF THE SPINAL CORD.
By WM. STIRLING, M.D., Sc.D., *Professor of Physiology
and Histology in the Owens College, Manchester.*

(From the Physiological Laboratory of the Owens College.)

THE number of substances employed in recent times to increase or diminish the excitability of the spinal cord has been gradually increasing. It seems, therefore, advisable that a systematic investigation of the precise effects produced by these drugs should be undertaken, with a view to testing physiologically their effects upon some of the lower animals.

The present investigation was undertaken with the view of ascertaining the effects of the chief salts of the mon-atomic metals upon the reflex excitability of the spinal cord of the frog. The research does not by any means pretend to be exhaustive—it is rather only a preparatory step in the direction indicated. The disposal of my time at present is such that I cannot easily obtain the number of consecutive hours necessary for carrying out such investigations, and I am therefore induced to publish these results in the hope that they may form a basis for future work.

A large number of investigations have been made in recent times on the conditions governing reflex actions in the frog,—amongst others, the results of Setschenow, recorded in his work “On the Electrical and Chemical Stimulation of the Sensory Spinal Nerves of the Frog,” a most important contribution to this subject. Türck adopted the method of stimulating the skin with a dilute acid, and Baxt, in Ludwig’s Laboratory, using the method of Türck, found that the latent periods of reflex actions increased in a geometrical progression, whilst the degree of acidity—dilute sulphuric acid—followed an arithmetical one. I undertook several years ago a similar investigation, using electrical instead of chemical stimulation.¹ A systematic

¹ Stirling “On the Summation of Electrical Stimuli applied to the Skin,” *Journ. of Anat. and Phys.*, x.

investigation of the effects of certain substances on the reflex excitability of the spinal cord was undertaken by Meihuizen¹ in 1873, where reference is made to the chief contributions to this subject up to that time. Important contributions have been made by Sydney Ringer and E. A. Morshead on the effects of the chlorides, bromides, iodides of potassium, ammonium, and sodium, on the afferent nerves of the frog's leg, and also on the body of the frog generally.

Method.—The method adopted in the present investigation was that of Türck, which was also used by Meihuizen in his experiments. The animal employed was *Rana temporaria*, because it is easily procured, and the epidermis is not so thick as in *R. esculenta*. As it was desired to act only on the spinal cord, and not on the brain, the animal was in all cases pithed. The brain and spinal cord were destroyed above the brachial plexus, and to prevent bleeding, the skull was plugged with a small piece of wood. The cord can be exposed and divided without losing any blood. If much blood be lost, of course it is necessary to reject such frogs. Three quarters of an hour—an hour—or even a longer time was allowed to elapse before the stimulation of the foot was begun. The chemical stimulus employed was a dilute solution of sulphuric acid—a fifth per cent. A hook was placed through the upper jaw of the frog, by which it was held vertically. One foot up to the level of the ankle was dipped into the dilute acid, and as soon as the leg was withdrawn the interval of time which elapsed between the dipping in of the foot and its withdrawal was noted; this time represents the latent period. The time was measured by means of a metronome, which was so arranged as to beat 100 times per minute. The metronome was allowed to beat, and the number of beats counted between the dipping in and withdrawal of the leg gave the latent time. On comparing this time before and after the administration of a drug, one can ascertain the effect of that drug on the latent period. Whilst one leg was being dipped into the acid, the other leg was gently held out of the way by means of a glass rod. On the leg being withdrawn, the legs were immediately bathed in ordinary water to remove the particles of acid adhering to the skin. The frog

¹ Meihuizen, *Pflüger's Archiv*, vii. 201.

was then placed on a plate, and covered by a bell-jar lined with moistened blotting-paper, so as to form a "moist chamber." It is desirable that the temperature be not too high; from 15° to 16° C. is the best temperature; if it be much higher than that, then the frogs are apt to lose their excitability too soon. A very important matter is at what intervals of time the stimulations ought to be made. This can only be determined by experiment. I found in my former experiments on the "Summation of Electrical Stimuli," that stimulation at intervals of a quarter of an hour allowed sufficient time for the nerves, muscles, and cord to regain their normal excitability, as shown by the fact that in a series of stimulations at intervals of fifteen minutes, the latent period remained unaltered even after several hours. I find exactly the same holds good for chemical stimuli, so that the leg in all cases was stimulated at intervals of a quarter of an hour. Baxt and Meihuizen obtained similar results. If the stimulation be undertaken every five minutes, then after a very few trials the latent period becomes greatly increased, and the excitability soon abolished altogether. Having determined, after a series of trials, the normal latent period, the drug to be investigated was injected under the skin of the abdomen, into the abdominal lymph-sac, and the effect on the latent period observed. If the drug, when injected in sufficient quantity, has no effect within two or three hours, then it may be concluded that it has no action on the cord; and further, if the effect occurs before that, it is due to the drug, and not to any effect of the stimulation *per se*. The effect is usually manifested much sooner than that. Meihuizen divided the brain on a level with the posterior margin of the tympanum, and injected the drug into the dorsal lymph-sac. In opening the spinal canal, I of course opened the dorsal sac; hence the abdominal sac had to be used.

To show the effect of simple stimulation without the injection of any drug, I may select the following, taken from a large number of similar experiments. The results are shown graphically, so that the effect of the stimulation may be seen at a glance.

The vertical line in all these curves at the extreme left indicates the number of beats of the metronome, each beat = $\frac{1}{100}$

min.; the horizontal line represents time, the interval between any two of the shorter lines = $\frac{1}{4}$ of an hour. Thus, the height of any of the lines or ordinates above the base line or abscissa represents the duration of the latent period.

In studying the results one finds that, speaking generally, the latent period is nearly the same at the end of five hours as at the beginning of the experiment, so that it is obvious that the

FIG. 1.—Latent periods of a reflex motor act when the frog's leg was stimulated at intervals of a quarter of an hour. No drug administered.

cutaneous and motor nerves and the cord are not materially influenced by the method *per se*, when sufficient time is given them to recruit between the successive stimulations. There is one point, however, which is very marked in some cases, and it is this, that when a considerable interval, say several hours, have elapsed between two stimulations, then usually the duration of the latent period is greatly lengthened at the first, and it may be at the second, stimulation thereafter.

Sodium Salts.—I have studied the effects of several of these salts upon the reflex excitability, and my results agree with those of Meihuizen and others.

Sodic Chloride.—The solution employed was such that each minim contained .01 gramme of pure NaCl. A large number of experiments were made, but, to save space, the figures are omitted, and one typical result is given in a graphic form. In reducing these figures to a graphic form, a vertical line

running through the curve indicates when the drug was injected into the lymph-sac.

All these experiments indicate exactly the same result, viz., that when sodic chloride is injected under the skin of a frog in successive quantities equal to .04-.08 grammes, it has no effect on the reflex excitability of the cord. It is worthy of note, how-

FIG. 2.—Showing the effect on the latent period of the injection of successive doses of sodic chloride. 0.2 grms. of sodic chloride injected at *a*, *a'*, *a''*, *a'''*, total .08 grms.

ever, that in fig. 2 the same result, viz., a prolonged latent period after a considerable interval of time—seventeen hours—is manifested, as in those cases where no drug was injected (fig. 1).

Further, it sometimes happens that when no reflex effect is obtained even after two to three minutes of chemical stimulation, yet the frog may react slightly to a strong mechanical stimulation. This is true also of non-poisoned frogs.

In some cases the frog gives only a very slight twitch or movement of its foot, without actually drawing it out of the acid. In those cases this twitch is almost invariably followed, several beats later, by a well marked reflex contraction sufficient to lift the foot out of the acid. I have in the paper already referred to, on the "summation" of sensory impressions, called attention to these "preliminary" contractions,¹ which seem

¹ *Loc. cit.*

to depend upon an imperfect discharge of the energy in the cord, thus so far interfering with the summation of the stimuli in the cord, and delaying the complete contraction until impulses sufficient in number and intensity reach the cord to overcome the resistance, and thus to cause a complete contraction which occurs *later*. These "preliminary" contractions occur not only in intact frogs, but also after the administration of drugs (fig. 5).

Sodic Bromide.—This substance has been extensively used as a substitute for the corresponding salt of potassium, but, as far as my observations go, they show that it is much inferior to the corresponding potassium salt in potency—a fact noted by all observers; and in fact it seems to exert very little, if any, effect on the reflex functions of the cord even in considerable doses (.12–.14 grammes). One minim of the solution

FIG. 3.—Effect of sodic bromide on the latent period in a frog weighing 29 grms. .02 grms. at $b-b''$, .03 grms. at b' , b'' , total .14 grms.

injected contained .005 grammes of NaBr. Without giving a lengthy protocol, I append a curve (fig. 3) which shows that the reflex spinal excitability is not materially influenced by it.

These results show that in double or treble the toxic dose of the potassium salt, it produces no effect. This result coincides with that obtained by J. V. Laborde.¹

Sodic Iodide.—This seems also to be a very inactive preparation: .12 grammes produce no marked effects.

Potassium Salts.—The poisonous effects of the potassic salts on the heart and central nervous system are well known, from the researches of Bernard and Grandeau, Guttman, Traube, Podcopaew, Ringer, and Morshead. My results are similar, and

¹ *Journal de l'Anatomie et de la Physiologie*, Robin, 1868, p. 560.

show the energetic action which these salts exert upon the central nervous system in addition to their effects on the heart.

In fig. 4, after .02 grammes, the latent period within a few minutes rises enormously, it becomes four times longer, and then falls within an hour and three quarters to fifty per cent.

FIG. 4.—Effect of potassic chloride on a frog weighing 28 grms. .02 grms.
at c, c', total .04 grms.

above the normal, when another dose of .02 grammes increases it to five times the normal amount. It is obvious, therefore, that this substance has a very depressing effect on reflex action. We shall consider presently whether this result is due to its effect on the cord directly, or nerves, or to its action on the heart and circulation.

In fig. 5 we have an excellent example of a frog in which the "preliminary" contraction occurred almost uniformly before the second well-marked one, so that a double curve is obtained, and it is remarkable how nearly these two curves coincide. The lower dotted one represents the series of "preliminary".

contractions where present, and the continuous line the curve of the complete contractions. In this frog, which weighed 89 grammes, .02 grammes were sufficient to extinguish the reflex excitability.

. As to the question whether this salt has an action on the central nervous system apart from its action on the heart and

FIG. 5.—Effect of potassic chloride on the reflex excitability on a frog weighing 89 grms. The upper curve represents the final complete reflex, the lower one the preliminary contraction. Weight of frog 89 grms. .005 grms. at $c-d''$, total .02 grms.

circulation, there can be no doubt that it has, for I have frequently found the circulation in the web quite active when the reflex excitability was abolished, both for chemical and mechanical stimulation, and when both muscles and nerves

responded to electrical stimulation. My results therefore agree with those of Ringer and Morshead, who also found the circulation active after complete cessation of the reflex excitability. It is known that besides their action on the spinal cord, that the potash salts paralyse the ends of the motor nerves.¹

In poisoning with potash salts, the frog's skin becomes very dark. This has also been observed by Meihuizen. I have always observed that the effect is more pronounced in the skin over the seat of injection.

Potassic Bromide.—There is no doubt whatever about the action of this drug on the reflex apparatus. It manifests its depressing effects in small doses. In one case .03 grammes of potassic bromide were administered, and a marked effect on the latent period was rapidly produced—viz., an enormous increase of the latent period, i.e., a pronounced diminution of the reflex excitability. In other cases one observes that after the drug begins to act it shows its effects very markedly within one or two periods of stimulation, so that the numbers in the latent-period column often run up, as it were, at a bound from 15 to 88 or more, the reflex excitability being rapidly abolished.

I have observed one most important fact in connection with the action of potassic bromide on frogs. In cases where the reflex action has been completely abolished, and where the circulation may still be active in the web of the foot, if such frogs are kept until next day or the day after, they often manifest peculiar muscular twitchings or spasms on being touched,—it may be in almost all the muscles of the body, or they may occur in the belly muscles, or those of the arms or legs. There may be an attack just like a general attack of tetanus; and after this passes off, certain of the muscles, as those of the belly and forearm, may continue in a state of tremor. This effect is due to some effect produced on the *central* mechanism in the cord, for it disappears if the nerve supplying the muscles is divided. Perhaps this condition may be comparable to that which Thomas R. Fraser found occurring in frogs several days after they were poisoned with sulphate of atropia. At anyrate, the effect is well marked, and seems to depend upon some direct action on the central spinal mechanism.

¹ Brunton's *Pharmacology*.

The potassic bromide undoubtedly acts on the central reflex mechanism in the cord, for it is usual to find that the circulation in the web of the foot is still quite active even after all reflex action is abolished, and when motor nerves and muscles are still quite excitable.

There is one point, however, in the mode of action of potassic bromide which is important. It was noticed by Purser,

FIG. 6.—Effect of potassic bromide on a frog weighing 61 grms. .02 grms.
at *b*, *b'*, total .04 grms.

Lewisky, Laborde,¹ and others—viz., that when the action of the poison—on intact frogs with their brain present—has advanced so far as to cause flaccidity of the muscles and absence of reflex action, the animal may give a sudden spring or jump. These

¹ *Journal de l'Anatomie et de la Physiologie*, p. 559, 1868.

voluntary movements show that, in the frog at least, the action of the drug is not chiefly exerted on the cerebral centres, but either on the central reflex spinal mechanism, or the afferent nerves to the cord, or both. The motor tracts which lead from the cerebrum to the muscles are not affected, whilst the reflex mechanism undoubtedly is. Here we seem to have a drug which shows that the motor tracts from the brain through the cord are, in part at least, distinct from the reflex paths. It is undoubted that the effect is not due to the action of the drug on the motor nerves or muscles, for they are found to be excitable after death.

Potassic Iodide.—I have, so far, not obtained any constant results with this drug.

Lithium Salts.—There is no doubt, from the experiments to be mentioned, that the lithium salts exert a stimulating action on the central nervous system of frogs, which are readily thrown into a state of spasm or tetanus after a moderate dose of certain of the lithia salts. In experimenting with lithic chloride I very frequently found that after the animal had been poisoned for several hours, and had had many attacks of continued spasmodic or tetanic contractions of the voluntary muscles, that the animal ejected its stomach, i.e., the stomach was found in the mouth completely everted, having been forced through the œsophagus.

Lithic Chloride.—In experimenting with this drug, as in all others which cause spasmodic muscular contractions, it is very difficult to give a graphic representation of the results of its action, such as may be called a typical curve, as in the case of the corresponding salts of potash and soda. The effect produced depends partly on the dose and partly on the excitability of the frog.

In some cases a moderate dose, .02 grms., seems to abolish the reflex excitability to chemical stimulation almost at once, although a very feeble reflex effect may be obtained to very powerful mechanical stimulation, while in other cases the latent period is increased, sometimes doubled, in the first stimulation after injection of the drug, and then no reflex effect is obtained for several periods thereafter. But in one case, about an hour and a half after the injection, the frog was seized with sudden

general spasmodic contractions of all the muscles of the body, so much so that the animal, although lying on its belly, was forcibly turned right over, so that it came to lie on its back. There was violent extensor tetanus, just like the condition produced by strychnia poisoning. Thereafter the muscles of the lower limbs remained in a state of tremor. After a time a reflex contraction was obtained after 89 beats of the metronome—that is, about $\frac{2}{10}$ ths of a minute. This result—the long latent period—is largely due to the exhaustion of the spinal cord from the continued spasms, which have a central origin.

In other cases it is difficult to ascertain the immediate effect, although on the whole it seems to be to lengthen the latent period. This may occur very gradually up to a certain extent—trebled or quadrupled—and then suddenly the animal is thrown into a state of violent tonic spasm, as described above.

Sometimes it is very difficult to ascertain the effect in the first two or three periods after the injection of the drug, in consequence of the movements of the lower limbs which are sometimes induced. When the animal is held up, it, as it were, treads the air. In all cases, sooner or later, the co-ordinate reflex to chemical stimulation is abolished, and gives place to tetanus.

In all cases the drug produces marked muscular spasms, which may begin as muscular twitchings in the toes, and extend to other muscles of the body until all are involved. In some cases the abdominal muscles contract most powerfully. In not a few cases the animal is forcibly thrown on its back.

In almost all cases when the frogs were left under a bell-jar and in a moist atmosphere for the night, in the morning they were found with their stomach and lower part of their oesophagus everted, and, as it were, projected through their mouths. The stomach was everted, and appeared as if it had been forcibly everted and pushed from below by the violent contractions of the abdominal muscles.

The muscular tremors often lasted for many hours—until the next morning. Sometimes fibrillar muscular contractions were observed. The spasms ceased when the nerve supplying the muscles was divided, so that their origin is central.

The heart was usually found beating, and the circulation in

the web active, so that this drug has an action on the central nervous system apart from any action it may have on the heart.

The muscles and nerves were excitable to mechanical and electrical stimulation, so that its action is chiefly central, and, as far as I have investigated it, on the spinal cord.

Lithic Bromide.—In certain respects the action of this drug resembles the chloride of the same metal, but it is inferior in its activity. In some cases more than double the dose is required to obtain any effect. In one case .09 grms. of Li. Br. and .08 grms. required to be injected before any effect was produced, and then there was a sudden increase of the latent period, and the animals passed rapidly into a state of spasm—often beginning in the muscles of the toes, exactly like the effects of lithic chloride. There was well marked opisthotonos — tremors and violent contractions of the abdominal muscles and limbs, so that the animal was almost thrown off the plate on which it was placed. Sometimes, after a violent attack of tetanus, and when no co-ordinated reflex movement was obtained from chemical stimulation, after half an hour or more, a co-ordinated reflex movement was obtained, usually with a greatly elongated latent period.

In other cases the reflex excitability to chemical stimulation seems to be rather suddenly extinguished, especially if a series of doses has been administered without any apparent effect.

In those cases where the reflex effect was abolished, the heart was found beating, and the muscles and nerves were excitable.

Lithic Iodide.—The frogs were operated on the evening before, so that seventeen hours elapsed before the experiment was commenced. This interval I have found to have no effect on the latent period except at the first stimulation, which usually gives a very long latent period, which becomes normal at the second stimulation. The effect of a prolonged period of rest in increasing the first latent period has already been noticed.

The action of lithic iodide resembles in some respects that of the chloride and bromide. There is an elongation of the latent period usually after a considerable dose or series of doses; this effect may last for a considerable time without the animal exhibiting any muscular tremors for some time, or the latent

period may be rapidly prolonged, and the animal be thrown into a state of rigid tetanus, often lasting several seconds—and that within half an hour, or even less, after the drug has exhibited its effect on the latent period. In all cases these muscular tremors and tetanic contractions were observed, although in some cases their appearance was delayed until several hours after the injection of the drug. In some cases the reflex to chemical stimulation was abolished for a considerable time, and recurred again. The circulation in the web was active, even although the reflex was abolished.

On the succeeding morning, in almost all cases the frog was found to have its stomach everted and lying in its mouth, just as in poisoning with the chloride. The slightest touch sufficed to throw a quiescent frog into a state of tetanus after the spasms had once set in. The cause of these contractions lies in the cord.

It is obvious, therefore, from these experiments, that the lithium salts are much more poisonous than they have been suspected to be heretofore. In all cases they cause violent muscular tetanus, which has a central origin (spinal cord), and this increased excitability at this stage is so marked that the slightest touch suffices to cause the frog to be thrown into violent extensor tetanus. This period of exalted reflex excitability seems to be preceded, in some cases at least, by one of diminished excitability to reflex stimulation. These effects seem to be due to the action of the lithium on the spinal cord, and not to any action it may have on the heart. As all the salts of lithium investigated produced the same effects, it is obvious that it is the base—the lithium—which is the active agent in producing these results, and not the acid,—a principle which has already been fully confirmed by many observers. In the case of some of the alkalies, however, the action of the salts depends much on the acid.

The remarkable action of the lithia salts in causing eversion and expulsion of the stomach into the mouth has already been alluded to.

Lithium in its action has less resemblance to the soda and potash salts than to those of ammonium, which will be alluded to when we record the actions of these salts.

Ammonium Chloride.—On injecting the solution into the abdominal lymph-sac there did not appear to be so much irritation produced as with lithic chloride.

The spasms occur very readily when the frog is lifted to test the reflex excitability. Sometimes the muscles of the back are so rigidly contracted that there is well marked opisthotonos. The toes are sometimes spread out so that the web is rendered tense.

After a time the reflex action may be abolished, but even under these circumstances the heart is usually found beating, and the muscles and nerves excitable. In a few cases the heart was found beating, and the muscles still excitable, although the motor nerves had lost their excitability. Nothing comparable to the eversion of the stomach was found.

The action of ammonium chloride on frogs seems to resemble very closely in certain respects that of the lithium salts.

A relatively small dose ($\cdot 02$ grammes), or even $\cdot 01$ in some cases, very soon causes pronounced effects.

In some cases the latent period, after the injection, is increased, whilst in others it appears to be shortened somewhat;

FIG. 7.—Effect of ammonium chloride. Weight of frog 31 grms.
 $\cdot 01$ grms. at c, c', c'', total $\cdot 03$ grms.

but if another small dose be given, the latent period soon rises, and then there occurs—suddenly it may be—a general tetanic convulsion of all the voluntary muscles of the body. Sometimes

tremors begin in the forearms or legs, and gradually extend to the rest of the body, until the frog's limbs become quite as rigid as in strychnia poisoning.

Buchheim states that ammonium chloride has not the same effect as the other salts of ammonia. This is certainly an error, for, like F. Lange, I find it is one of the most powerful of the ammonium salts; and this is what one would expect, for the injection of the ammonium salts into the veins of a mammal causes violent general convulsions of all the voluntary muscles, which occur soonest after the injection of the carbonate and then of the chloride (Boehm and Lange). Indeed, these two observers say that ammonium chloride is the most poisonous ammonium salt with which they experimented (mammals).¹

Ammonium Bromide.—Here, as in the other cases when spasmodic contractions are caused by a drug, it is very difficult to obtain the latent period.

In some cases there is an elongation of the latent period, which after a short time is followed by twitches in one or more of the limbs, or by general convulsions, just as is the case with the chloride, only it would seem that a somewhat larger dose of the bromide is required than of the chloride. Indeed, Ringer and Morshead found that the ratio of the chloride and bromide to the iodide might be represented by 1 (C): 1·5 (B): 2 (I) if the frog is to obtain the same amount of potassium or ammonium. After a time, reflex action is entirely abolished.

In some cases the reflex activity seems to be partially restored, provided the dose has not been too large. The circulation may be quite active even when no reflex can be obtained in response either to chemical or mechanical stimulation. The muscles and nerves were found to be excitable to electrical stimuli.

I have not entered into the question of the relation between the chemical constitution of the drug used and its physiological action, a subject discussed by Brunton and Cash.² The expenses of this research were defrayed by a grant from the British Medical Association.

¹ *Archiv f. Experimen. Pathol. u. Pharmacol.*, ii. 364.

² *Trans. Roy. Soc.*, part i., 1884.

THE GUSTATORY ORGANS OF *ATELES ATER*. By
FREDERICK TUCKERMAN, *Amherst, Massachusetts*.

THE tongue of *Ateles* possesses a long flattened process, which is continued forward from the frænum. This lingual character, already noted by Owen in the *Lemuridæ* and *Chiromyidæ*, is called the frænal or sublingual plate. A peculiar interest attaches to the frænal plate in *Ateles*, as it represents a hitherto undescribed bulb-bearing area.

General Description of the Tongue.—The organ measures 54 mm. in length, 20 mm. in breadth, and is free from the frænum for 12 mm. It is quite thick posteriorly, and the general surface is smooth and yielding to the touch. The under surface of the free portion is impressed by a deep wedge-shaped groove extending from the frænum to the tip. The fungiform papillæ are abundant only at the tip; beneath it, they are large and closely packed. As in *Lemur mongoz*, and some species of *Macacus*, the circumvallate papillæ consist of two pairs. The posterior pair are 2.6 mm. apart, and 13 mm. from the base of the tongue. The anterior pair are well forward, being 10 mm. from the posterior pair and 11 mm. apart. The two pairs of papillæ, seen from above with a low power, show a marked difference in external characters. The summits of the posterior pair are smooth and circular. The anterior pair, on the other hand, lie more obliquely, present a less regular contour, and are somewhat depressed at the centre. Within the space bounded by the four gustatory papillæ are three transitional forms, which are obviously modifications of the fungiform type. The dorsum posterior to the gustatory region is wrinkled, but devoid of papillæ. The lateral gustatory organs are placed obliquely at the sides of the base, very much as in *Lepus*. The fringe of the filiform papillæ is wanting. The frænal process or sublingual plate noted by Hunter in *Lemur mongoz*, and subsequently observed by Owen in other *Lemuridæ*, is a lingual character in *Cebus*, *Macacus*, and *Ateles*. In *Ateles* the process is flattened, the tip bifurcate,

and the edge more or less fimbriated. It measures 6.5 mm. in length, and 4.5 mm. in width at point of attachment to the frænum.

Gustatory Structures.

The Circumvallate Papillæ.—Papillæ vary greatly in size, and are occasionally lobate. The summits of the anterior pair do not project from the openings of the trenches, and hence they are more protected than the posterior pair. They measure from 0.70 to 2.30 mm. transversely, and are 0.75 mm. in height. Serous glands are fairly abundant and occur within the papillæ. The ducts open at the usual places. The bulbs are disposed on the lateral area of the papillæ in ten tiers. A few scattered bulbs are also present on the free upper surface, and, more rarely, may be found embedded in the epithelium of the outer wall of the trench. The bulbs are closely set, and, in crowded tiers, number one hundred and forty. The mean is probably one hundred. They measure 0.051 mm. in length and 0.027 mm. in breadth.

The Lateral Gustatory Organs.—The organs are flattened or slightly rounded on top, and measure 8 mm. in length and 4.5 mm. in breadth. The folds are fairly uniform in size, and twelve of the fifteen bear bulbs. The furrows are narrow, and measure 0.65 mm. in depth. Serous glands are fairly plentiful and occur within the folds. The ducts open into the furrows at their deeper part. The bulbs, of which there are some ten tiers, measure 0.051 mm. in length and 0.027 mm. in breadth.

The fungiform papillæ are of normal structure. Those about the tip, more especially its under part, are richly supplied with bulbs. Here they are numerous but small, and in some papillæ form a row of ten or more, which extends across the entire width of the summit.

I failed to detect terminal bulbs in the sublingual plate in *Cebus* or *Macacus*. In *Ateles*, however, they are quite numerous, especially in the fungiform papillæ, where I have counted as many as sixteen bulbs in a single vertical section. They are also embedded in the epithelium of the free margin to some extent. One that I measured was 0.065 mm. in length,

the average length, however, is 0·048 mm., the breadth being 0·030 mm. Non-medullated nerve-fibres enter the axes of the fungiform papillæ of the plate, and form a network beneath the bulb-bearing region. Glands, presumably of the mucous type, are present; there being a main central clump, and, near each lateral border, a smaller one. It is highly probable, I think, that the sensory terminal organs of the sublingual plate are tactile rather than gustatory in function.

ON A METHOD OF EXAMINING BLOOD, BONE,
MARROW, &c. By ROBERT MUIR, M.A., M.D., *Assistant
to the Professor of Pathology, Edinburgh University.*

IN examining blood in normal and in pathological conditions, I have chiefly employed till recently two methods of making permanent preparations; viz., Ehrlich's method of making films, which are dried, and afterwards fixed by heating, and the method of fixing the blood by dropping it into Flemming's strong solution, imbedding the drops in paraffin, and cutting sections. The latter method shows the structure of leucocytes, &c. very well, and is specially valuable in cases of leucocythæmia where the leucocytes are numerous; but the characters of the red corpuscles are poorly shown, and in ordinary conditions few leucocytes are seen in one section. Ehrlich's method, if properly employed, preserves the characters of the red corpuscles well, and fixes the hæmoglobin, besides having other advantages, but the structure of nuclei is not so well preserved by it, especially if these be of large size, as in many of the cells of the bone marrow. The following method overcomes these disadvantages. Films of blood are made on cover-glasses, as in Ehrlich's method, care being taken to avoid any pressure on the films. These are then placed at once, before any drying can occur, with the films downwards, on the surface of a saturated solution of corrosive sublimate with $\frac{3}{4}$ per cent. sodium chloride added,—preferably heated to a temperature of

about 50° C. (though this latter is not essential), and are allowed to remain for about half an hour. They are then thoroughly washed in $\frac{3}{4}$ per cent. common salt solution, taken through successive strengths of alcohol, and then stained in the same way as sections. I also add salt in the same proportion to the weaker strengths of alcohol. In many cases some of the steps may be admitted, but I find that the hæmoglobin and nuclear structure are best preserved if the method is used as described. In the case of the bone marrow, a little of the pulp is brought in contact with a cover-glass once or twice, so as to make a layer, but it ought not to be spread out, *e.g.* by a glass-rod, as thereby the cells become distorted. The cover-glass is then placed in the fixing solution. Spleen pulp, the juice of lymphatic glands, of tumours, &c., can be treated in the same way. The stains which I have found most useful are Ehrlich's acid hæmatoxylin with aurantia or with eosin, saffranin with aurantia, the triple stain of saffranin, hæmatoxylin and aurantia, and Biondi's triple stain.

The advantages of the method are that permanent preparations can be made with comparative rapidity—in little over an hour—that the hæmoglobin is fixed in the red corpuscles, and that the structure of nuclei is well seen. Especially the chromatin threads in mitotic figures appear with great distinctness, and I have accordingly found the method very useful for photographic purposes.

ON THE PEDAL SKELETON OF THE DORKING FOWL, WITH REMARKS ON HEXADACTYLISM AND PHALANGEAL VARIATION IN THE AMNIOTA. By G. B. HOWES, *Assistant Professor of Zoology, Royal Coll. Sci. Lond.*, and J. P. HILL.

I. *Special.*

THE Dorking fowl is well known to be the only living bird possessed in the adult condition of a pentadactylous pes. The only recorded descriptions of its pedal skeleton are those of adult structure, and Mr J. Cowper has made the study of its pes the subject of two special communications to this *Journal*.¹

His descriptions and figures show that while the two innermost digits of this pes may bear each but two phalanges, three may be present for either the one or the other, and that the increase in length of the entire digits is proportionate to that in number of their phalanges. There have recently come into our hands the feet of a couple of Dorking Chicks in which (*cf.* fig.) the conditions were both otherwise and especially interesting, as we now proceed to show.

In the older specimen (figs. 1 to 3) the three outermost digits, with their tarso-metatarsus and phalanges, were normal for both feet; and the distal tarsal elements, although still cartilaginous, had completely fused with the heads of the metatarsals. The two innermost digits were symmetrical on either side throughout their phalangeal regions, but while the outer of the two (*i.*) bore but two phalanges on each foot, the inner one bore four. Fully-developed articulations were formed in relation to the individual phalanges.

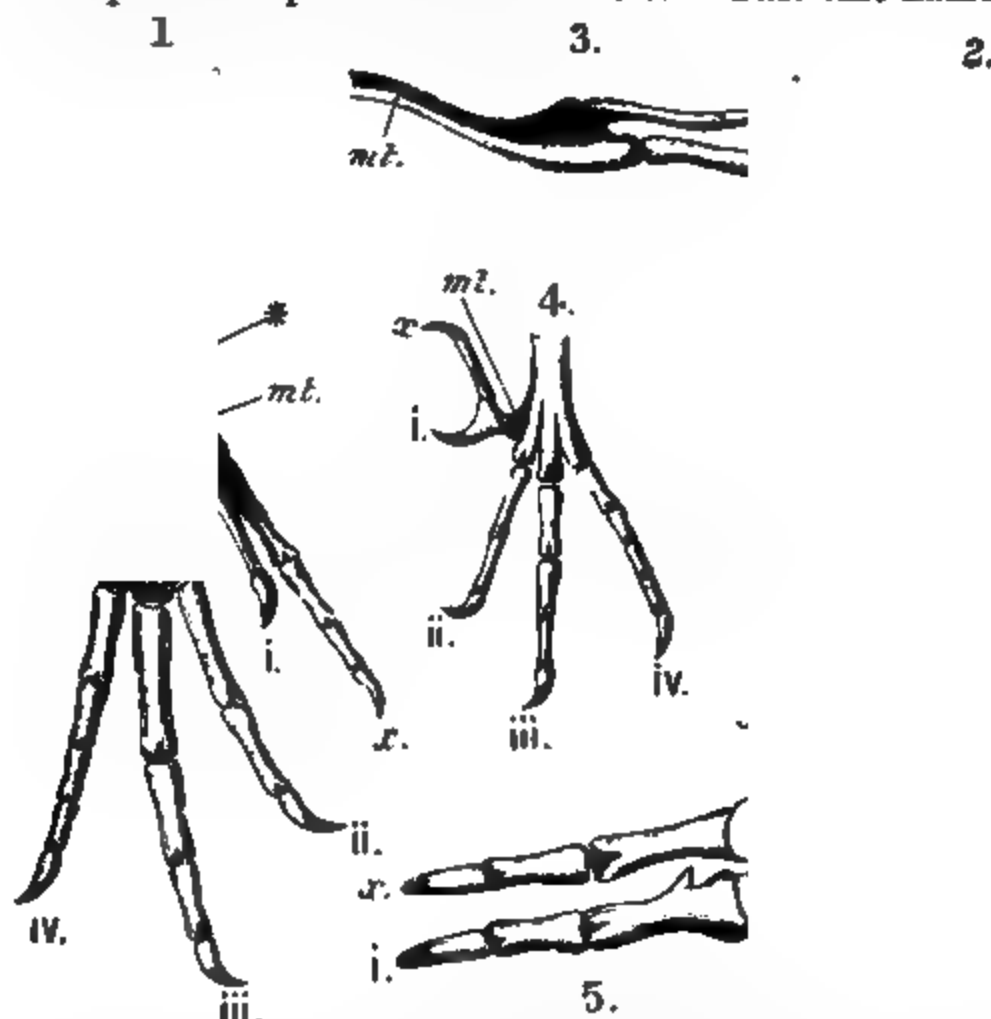
The two innermost digits of the Dorking fowl's pes are well known to possess a conjoint metatarsal, and Cowper has shown that while this may remain free, as does the hallux metatarsal of the common fowl, it may be completely ankylosed to the adjacent tarso-metatarsus. In our own example now under consideration, the relations of this element were, on both sides, exceptional and interesting. As compared with Cowper's figured specimens, its distal extremity was relatively remote

¹ *Jour. Anat. and Phys.*, vol. xx. pp. 598-595; *ibid.*, vol. xxiii. pp. 242-249.

from that of the tarso-metatarsus; and comparison with the adult shows that elongation of the tarso-metatarsus, subsequent to ankylosis, must be in this bird chiefly the result of proximal extension. In the right pes (fig. 1) this innermost metatarsal (*mt.*) was firmly ankylosed to the adjacent tarso-metatarsus; and the ankylosis had been accompanied by an inward and downward rotation of the first-named bone, whereby its proximal extremity (*, fig. 1) was caused to project freely upwards and inwards above the level of the dorsal border of the tarso-metatarsus. Comparison with an adult in our possession, in which the tarso-metatarsal elements were all immovably united, suggests that a prominent tubercle present on the dorso-internal border of the specimen may be its serial homologue. The two innermost digits of this pes, when viewed from above, were seen to be more nearly superposed than appears to have been the case with all adults hitherto described, and this as the direct result of participation in the rotation of their metatarsus already alluded to (*supra*). In the left pes of this chick (fig. 2) this superposition of the two innermost digits had become absolute, and the outer of the two (*i.*), which lay dorsad of its fellow (*x*), articulated upon the metatarsal element at a higher and more proximal level than the other. As the result of these changes, the innermost metatarsal had an inverted Y-shape (*mt.*, figs. 2 to 3); its most remarkable feature, however, was its proximal elongation to form a rod of bone running parallel with the adjacent metatarsals, and articulating (through the mediation of its united and cartilaginous distal tarsal element) upon the inner condyle of the tibio-tarsus. This perfectly unique feature presents us with a reversional condition of the hallux metatarsal, not only unrepresented in the adults of all known birds, but in the ontogenetic development of those whose life-histories have been worked out—a stage in evolution, moreover, through which the avian reptile *Archæopteryx* had itself passed, for the nearest counterpart of which we must go back upon the less aberrant tetradactyle Dinosaurs.

The second chick which we propose to deal with was much younger than that above described. Its feet (*cf.* fig. 4) were symmetrical on both sides; and, as with some of the adults described by Cowper, the two innermost digits bore each two phalanges. The basal phalanx of the outermost of these two

digits was in articulation with the metatarsus (*mt.*); that of the innermost digit (*x*) however, instead of articulating with the metatarsus side by side with its fellow of the outermost digit, as appears to be more generally the case,¹ was set upon an outgrowth of the proximal phalanx of the latter. This last-named bone



EXPLANATION OF FIGURE.—Pedal Skeleton of Dorking Fowl. 1. Right pes of advanced chick, dorsal aspect. 2. Left pes of the same, dorsal aspect. 3. Hallux metatarsal of fig. 2, inner aspect. 4. Left pes of a younger chick, dorsal aspect. All $\times 2$. 5. The two innermost sets of phalanges of the left pes of an adult, two-thirds natural size. i-iv, Digits, 1 to 4. *x*, So-called prehallux. *mt.*, Hallux metatarsal.

had the same inverted Y-shape as the innermost metatarsal of the specimen previously described (*ante*, p. 396), and, on comparison of the two structures with Cowper's figure in which the free metatarsal appears to have been in an essentially similar condition,² we incline towards a belief that the two innermost digits of the Dorking fowl's pes are the products of cleavage of the hallux, and that the differences between the specimens herein described and those of Cowper (apart from variation in number of their phalanges) are those of degree of longitudinal subdivision.

¹ Cf. Cowper, *loc. cit.*, i. p. 598.

² *Loc. cit.*, ii. p. 249, right-hand figure.

II. *General.*

In the earlier of his two papers on the Dorking fowl's pes Cowper sought to show¹ that the digit usually regarded as the "hallux, possessing two phalanges, is really the second toe, and that the toes usually called 2nd, 3rd, and 4th are the 3rd, 4th, and 5th; the missing toe in a four-toed bird being not the 5th but the hallux, and the so-called hallux being the 2nd toe."

Falling back upon argument by pure analogy to the mammalia, in which (citing Flower) he says that "if only one toe is absent it is the first or hallux," he deduces the final conclusion that "the bird follows the mammalian rule in this respect." And, finally, in his later communication, dealing with a hexadactyle individual, he remarks:²—

"After eliminating the cases which are due to partial or complete duplicity of limbs, and judging from the foregoing facts presented by amphibians, reptiles, birds, and mammals, bearing upon the question of hexadactylism,³ it seems possible to look upon the condition occurring in man, as well as in other vertebrates, as a case of reversion to a hexadactylous form."

His first proposition would thus affirm that the hallux and not the fifth toe is that which is unrepresented in all tetradactyle birds, and that the Dorking fowl has alone retained the missing member. Four years prior to the publication of Mr Cowper's first communication, the late W. A. Forbes showed⁴ that the avian pes does *not* follow a uniform plan of modification, and he emphasized his position by proving that the hallux is not always absent even in the tridactyle birds. He showed that in the Kingfishers of the genera *Ceyx* and *Alcyone* possessed of a tridactylous pes, it is the second digit and not the hallux which undergoes suppression. Kükenthal has more recently discovered, on the mammalian side, that in the whalebone whales it is the middle digit of the manus which has suffered suppression and not the pollex as has been universally supposed.⁵

These facts, when added to those more generally known concerning the morphology of the avian and mammalian limbs,

¹ *Loc. cit.*, i. p. 595.

² *Loc. cit.*, ii. p. 248.

³ Being a résumé of certain of the well-known discoveries and assertions of Albrecht, Bardeleben, Baur, and Wiedersheim, involving theories of polydactylism, which, together with allied observations of others, he incorporates in his papers.

⁴ *Ibid.*, 1882, pp. 386–390.

⁵ *Anat. Anzeiger*, 1890, p. 709.

clearly show that mere argument from rude analogy will not suffice, and that the members of each class, having been subjected to a series of independent modifications, must be independently considered.

Cowper's whole argument rests on the assumption that the innermost digit of the pentadactylous Dorking fowl's pes is alone the true hallux; and, in his final attempt to defend it, he falls back upon the "pre-hallux" of the Anura, the "tibial-sesamoid," and those well-known fragments fringing the mammalian and amphibian limbs with which Bardeleben, and Wiedersheim and Kehler, have so emphatically dealt. The most recent enquiries into these structures have shown them to be in the highest probability distinct *sui generis* from the normal digits of the pentadactyle limb, if not from each other; and Miss Carlsson, who has lately adduced good reason for believing that the marginal nodules of the mammalian pes are progressive rather than vestigial in nature, advances equally cogent ones for rejecting hypotheses which would relegate them to a common category with the amphibian "pre-hallux."¹

It need hardly be pointed out that these more recent enquiries lend no support to Cowper's belief.

Despite the fact that the two innermost digits of the pentadactylous pes of the Dorking fowl invariably articulate upon one common metatarsus (*mt.* of figs.) comparable, in all its fundamental relationships to the rest of the limb, to the normal hallux metatarsus of other birds, Cowper has throughout regarded the digits themselves as distinct structures to be dealt with independently. In assuming this attitude he takes insufficient cognisance both of the variability in number of their phalanges (as compared with those of the more normal constituents of the pes), and of the fact that the variations met with in his specimens affect the two digits indifferently. The phalangeal formula for these two innermost digits in his examples was either 2·2 or 3·2. We are in possession of an adult skeleton in which the formula for the right pes is 2·3, that of the left (fig. 5) 3·3. This specimen is of importance as exemplifying the

¹ Alt. Carlsson, *Bihang till. K. Vet. Akad. Handl.*, Bd. 16, Afd. iv. pp. 1-40; also *Verhandl. d. Biol. Ver.*, Stockholm, Bd. iv. pp. 1-5; G. Tornier, *Arch. f. Naturgesch.*, 1891, Bd. 1, Hf. 2, pp. 113-204. (A full bibliography will be found incorporated in these monographs.)

maximum elongation of the hallux yet recorded, not only for the Dorking fowl but for any known bird; and, considered together with those facts which we have already emphasized (*ante*, pp. 396 and 397), it lends no support to Cowper's belief in the total independence of the two digits in question. On the contrary, it the more conclusively shows that these must be jointly considered, and therein supports our belief that they together represent a cleft hallux. That the facts are the more readily intelligible on this hypothesis it will, we trust, be admitted; and the recent discovery by Kükenthal¹ of an undoubted occasional splitting of the Cetacean pollex lends welcome and additional support to our argument.

If our belief in the derivation of the supernumerary digit of the Dorking fowl's pentadactyle pes by cleavage of the hallux be denied, the only alternative which appears to us warranted by the facts is that of regarding it as a product of early established lateral outgrowth of its fellow in articulation; and it may be remarked that the numerical increase of the phalanges, inexplicable on the grounds laid down by Cowper, when viewed from either of our alternative standpoints, presents only a minor difficulty under the existing state of our knowledge—which shows supernumerary phalanges to be everywhere the products of extreme specialisation.²

Comparison of the Dorking fowl's pes with that hexadactylous type of appendage met with in mammals in which the supernumerary digit occurs on the preaxial border, suggests an unmistakable similarity of modification between the two, especially in regard to the great number of cases in which the two innermost digits articulate upon a common metacarpal or metatarsal element. This has been lately most clearly brought out for the manus by Prof. Windle, in a tabular résumé published in this *Journal*;³ and that author has with much justice remarked⁴ that these two innermost digits are, in consideration of their musculature, "much more of the nature of pollices than of that of the other digits." Reflection upon these facts appears to us to warrant the belief that a common interpretation will ultimately be found to explain both the

¹ *Anat. Anzeiger*, 1888, p. 912; 1890, p. 44.

² Cf. especially Kükenthal in Spengel's *Zoolog. Jahrb.*, Bd. v. (Syst.) Ht. 3, p. 373.

³ *Jour. Anat. and Phys.*, vol. xxvi. p. 100.

⁴ *Loc. cit.*, p. 106.

avian and mammalian conditions referred to, and that the deduction that the extra digit is in both types a product either of cleavage or lateral budding of the normal innermost one is that with which the known facts are to-day most readily harmonisable. If this be accepted, belief in the reversional character of the supernumerary digit or digits must needs presuppose the origin of normal ones either by a process of longitudinal splitting or of recurring lateral outgrowth of the limb bud. The known facts of development of the amniote limb show that the digits arise rather by the marginal fringing of a plate,¹ wherefore they lend no support to the reversionary theory. When, finally, it is seen that current research in palæontology is bringing us more and more to the conclusion that the Enaliosaurian paddle, so often invoked by the defenders of polydactyle limb theories, is the specialised derivative of the pentadactylous limb of a land reptile,² the only safe conclusions warranted by the facts concerning both the Dorking fowl's pentadactyle pes and that type of hexadactyle limb met with in the amniota before alluded to, is that, as concerns their supernumerary parts, they are both monstrous formations and nothing more, and that arguments deduced from their study in support of hexa- and hepta-dactyle limb theories are premature if not absolutely visionary. As affecting the evolution of the bird's limb, they are no more defensible than the excalation theory of Heusinger³ and Tschan,⁴ upheld, but subsequently rejected, by the late W. K. Parker.⁵

We take this opportunity of emphasizing a consideration which, while it must have occurred to the minds of others, has not, so far as we are aware, found its expression in print—viz., that of the affinities of the air-breathing vertebrata, as estimated by the digital characters of the classes thereof. It is everywhere known that the phalangeal formula of all mammals, other than the Cetacea, is 23333, or minus that number; and, if Kükenthal's recent argument⁶ in favour of the origin of the supernumerary phalanges of the Cetacea from dismembered

¹ Cf. especially Miss Johnson, *Quart. Jour. Micro. Sci.*, vol. xxiii. pp. 409 et seq., and pl. xxvii. fig. 8.

² Cf. Baur, *Zool. Anz.*, 1886, p. 245; *Berichte des Oberrheinisch. Vereins*, xx *Versammlung*; Fraas, *Die Ichthyosauria*, Tübingen, 1891; Kükenthal, *Zool. Jhb.*, loc. cit., and the works of Curioni and Seeley therein cited.

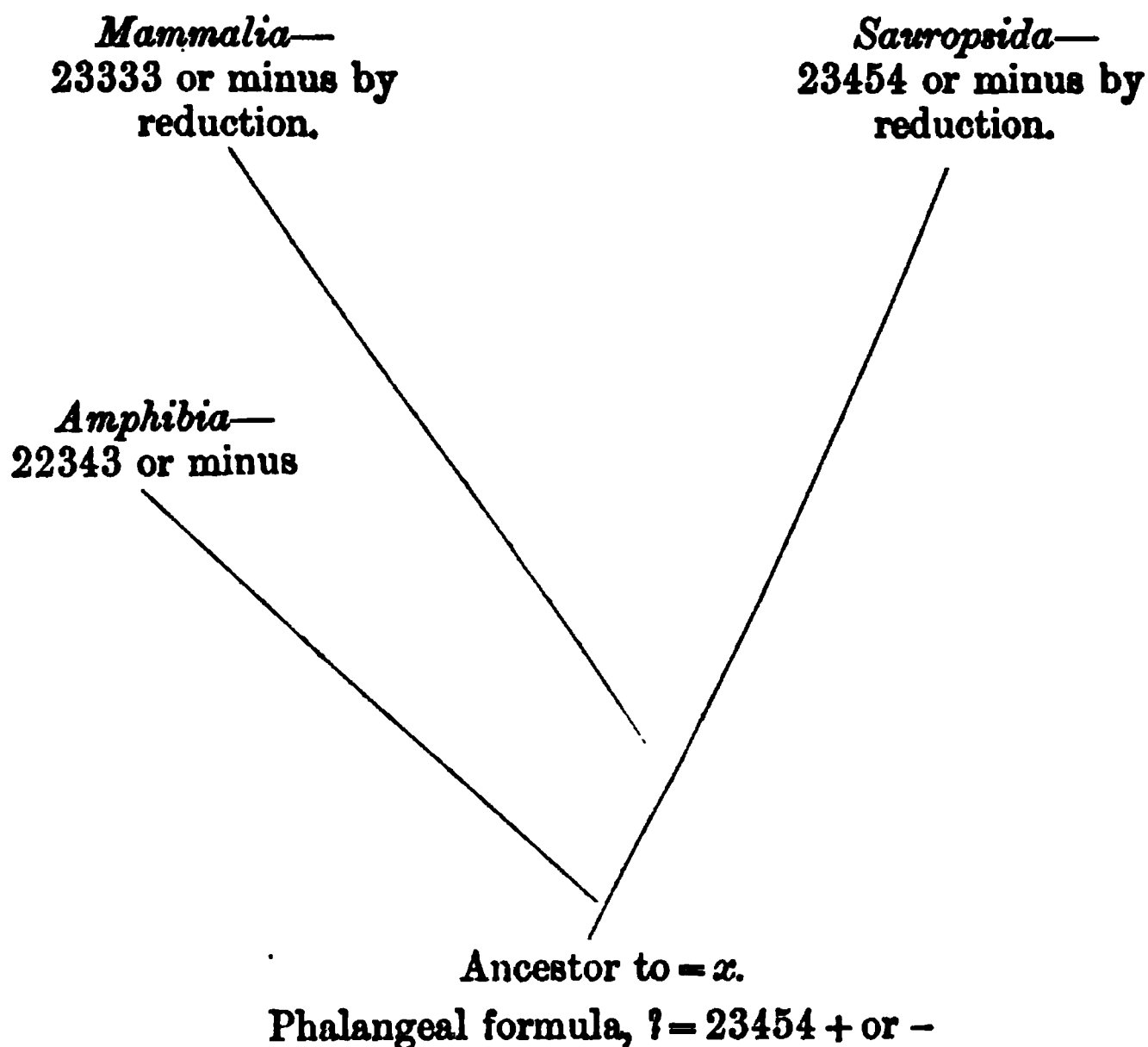
³ *Meck. Archiv*, Bd. vi. p. 546.

⁴ *Rech. s. l'Extrémité Ant. des Oiseaux e. d. Rept.*, Inaug. Dissert., Genève, 1889.

⁵ *Phil. Trans.*, 1888, B., pp. 391, 392.

⁶ *Zool. Jhb.*, loc. cit.

and duplicated epiphyses shall stand, the formula will remain diagnostic of the class. Passing to the lower vertebrata, we find that a structure originally described as a supernumerary phalanx among the Anura is the representative of an inter-articular syndesmosis,¹ and we think it not unlikely that that met with in the manus of the Chelonian genus *Chitra*² will be found to have a similar significance. Excluding these animals, and those in which there is reason to believe numerical increase of the phalanges to have taken place in adaptation to the requirements of an aquatic existence, the facts as they to-day stand may be expressed in the following tabular form.



The central consideration which we wish to emphasize is that inasmuch as no observed amphibian, either living or extinct, is known to have borne more than two phalanges upon its 2nd digit, neither the sauropsidan nor the mammalian types can be derived from that of the amphibia, except by a process of intercalation such as there is no evidence to support. The questions herein raised are sufficiently obvious, and for their solution we look rather to the palæontologist. As involving the

¹ Howes and Davies, *Proc. Zool. Soc.*, 1888, p. 495.

² Boulenger, *Brit. Mus. Cat. Chelonians, &c.*, new edit., 1889, p. 240.

mammalia, the force of the argument against a belief in the amphibian origin of the class is second only to that of Cope's discovery of the mammalian condition of the limbs in the Theromorphous Reptiles.¹

NOTES UPON THE SHOULDER GIRDLE OF CERTAIN
DICYNODONTOID REPTILES. By G. B. HOWES,
Assistant Professor of Zoology, Royal Coll. Sci. Lond.

THE following notes have arisen occasionally to the enquiry embodied in the concluding paragraphs of the foregoing paper by Mr Hill and myself, and I claim the bearings of the questions raised upon those of mammalian affinity as sufficient justification for publishing them.

Professor Seeley has lately described (*Phil. Trans.*, 1888, B., pp. 487-500) the remains of an anomodont reptile, which he has designated *Keirognathus cordylus*. In dealing with its shoulder-girdle he has laid stress upon the pronounced independence of a plate-like element which (after Owen) he terms a "pre-coracoid," and he likens this to the epicoracoid (termed by him the "pre-coracoid") of the Monotremata. All post-Owenian investigation into the morphology of the pectoral limb-girdle has rendered it more and more certain that if the term "pre-coracoid" is to be retained, it can only apply to the anterior or clavicular moiety of the former. Having been permitted to point out in this *Journal* (vol. xxi. p. 196) that the epicoracoid, regarded as a distinct component of the limb-girdle of living animals, exists only in the mammalia, I have been naturally much interested in Prof. Seeley's communication. In the same paper he incorporates a brief account of a fragmentary shoulder-girdle from the same beds as his *Keirognathus*, which Prof. Owen had previously described (*Brit. Mus. Cat. of the Fossil Reptilia of South Africa*, pp. 55, 56) as that of "a small Dicynodont;" and, in doing this, he asserts (p. 490) that it "may

¹ *Proc. Amer. Assoc. for the Advancem^t. of Sci.*, vol. xxxiii. p. 471.

possibly belong to the same genus as his own specimen (*Keirognathus*). Comparison of the Owenian fossil with the shoulder-girdle of the living Monotremes leaves little room for doubt that the element which Owen and Seeley have termed the "pre-coracoid" really is the Cuvierian epicoracoid. In describing the shoulder-girdle of his type specimen of the genus *Keirognathus*, Prof. Seeley speaks of this "pre-coracoid" (*loc. cit.*, p. 490) as apparently "excluded from the humeral articulation;" while the woodcut which largely does duty for his redescription of the Owenian fragment depicts it as entering considerably into the formation of that cavity.

It is not a little remarkable that Owen specially described this "pre-coracoid" (*loc. cit.*, p. 56) as excluded from the cavity in question. The bearings of this matter upon the problem of mammalian affinity will, I trust, be sufficiently obvious; and, having myself arrived at the conclusion (*loc. cit.*, p. 192) that the coracoid process of the Marsupialia and Placentalia is the homologue of the Monotreme's epicoracoid, and that the exclusion of this element from the glenoid facet is one of its most characteristic features, I have eagerly availed myself of the kindness of my friend Mr A. Smith Woodward of the Natural History Museum, and examined the fossils afresh. In the *Keirognathus* slab the locality of the presumed coracoidal elements reveals neither traces of skeletal material nor the certain impressions of coracoid bones, if ever they lay there. Indeed, the specimen is one of that class of objects which lend themselves to imaginary interpretation. The Dicynodont fragment shows that Owen's "pre-coracoid" may perhaps have entered into the glenoid facet to at most an insignificant degree; it is clear, however, that the girdle was that of a young animal, and that a considerable amount of cartilage must have been present at its articular border—a fact which renders it still less likely that the "pre-coracoid" furnished a part of the humeral articulation. It so happens that the trans-coracoidal suture is particularly well defined in the specimen, wherefore there can be no mistake about the boundary lines in question. Allowing for the foregoing remarks, Professor Owen's description is perfectly accurate. There is nothing in the specimen which warrants either the relations depicted in Prof. Seeley's woodcut (*loc. cit.*, p. 492, fig.

1), or the attitude assumed by him in removing the fossil from one provisional resting-place to another and less secure one which he has himself constructed. The specimen has since been with much greater reason referred by Lydekker (*Brit. Mus. Cat. of Fossil Rept. and Amphb.*, part iv. p. 52) to the dicynodont genus *Ptychosiagum*; but, although this author is silent concerning the humeral articulation, his woodcut (*loc. cit.*, fig. 2, p. 16) if anything exaggerates the error of that of Seeley. Lydekker interprets that lobe of the scapula which meets the Owenian "pre-coracoid" as the acromion, as opposed to Seeley who attributes that value to the reflected outgrowth of the pre-scapular border, lying dorsad of the lobe referred to. In doing this, Lydekker falls back upon the specimen numbered 47056* in the National Collection, in which he asserts the acromion of Seeley is "situated near the distal extremity" of the scapula. No such process is exposed in the specimen itself; but, as viewed through the wall case in which it stands, a mineral enclosure lying in position approximate to that of the alleged process might readily be taken to represent it. But, even were this not so,¹ the differences between the specimen and that of Owen and Seeley in respect to the process under immediate discussion, would be no greater than those between the undoubted acromion of *Ornithorhynchus* and *Echidna*, especially when variation with age and growth are taken into account. Concerning the process, the interpretation of Seeley is much the more in harmony with the known facts of morphology of the recent shoulder-girdle.

¹ Mr Lydekker has since described (*P. Z. S.*, 1889, pp. 573-575) the scapula of a similar reptile in which the process was in a somewhat more distal position; but I intentionally omit further comment upon that specimen and upon the undoubted coracoids of Prof. Seeley's *Procolophon* (*Phil. Trans.*, 1889, B., pp. 275-277), as they only secondarily affect the questions herein raised.

A CASE OF ABNORMALITY OF THE FINGER NAILS.

By W. RAMSAY SMITH, B.Sc., *Demonstrator of Anatomy
Edinburgh School of Medicine, Minto House.*

THE subject was a female infant, born at full term, well developed, and somewhat over the average size. The finger nails at first sight appeared to be longer than usual; but when closely examined they exhibited a condition different from anything that has come under my notice.

The nails of all the fingers and of the thumbs showed the same peculiarity. The root and the greater part of the body of the nail were quite normal; but as the thickened part of the skin overhanging the nail was traced forwards¹ it gradually became, on each side, quite continuous with the side of the nail, thus obliterating all trace of the curvilinear groove. At the place where the front of the nail ordinarily presents a free margin there was a whitish transverse mark (due apparently to the nail here being less dense), very closely resembling the free margin of the nail of a new-born child; but more careful inspection showed that although the nail at this spot was apparently less adherent to the nail-bed, there was really no free margin at all. The nail was continued like a cap or shield, or a veritable "hoof," downwards over the tip of the finger as a thin pinkish layer, quite inseparable from the underlying epidermis, and so continuous at its margins with the epidermis that one could hardly say where the nail stopped and the normal epidermis began (see fig. 1).

The nails were not interfered with for a week. It seemed at first as if they might break at the transverse markings, but they did not do so; the separation began at the most outlying margin, the separated part becoming whitish, wrinkled, and ragged. Some of the nails, which were giving trouble at the end of that time, were gently raised from the epidermis at their separated

¹ In this description I have not followed the usual method of anatomical naming, but have described the nail as looked at, back of the finger upwards, using the terms *forwards*, *downwards*, &c., in their popular meaning.

margins, and the freed portion was cut with a pair of scissors. In fig. 2, *a* and *b* show the lines of cutting, the distance between *a* and *b* being slightly exaggerated in the representation. The other nails were left undisturbed, and at the end of a fortnight they had grown to almost the normal shape, the thin cap

Fig. 1.

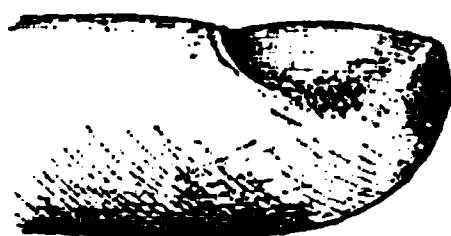


Fig. 2.

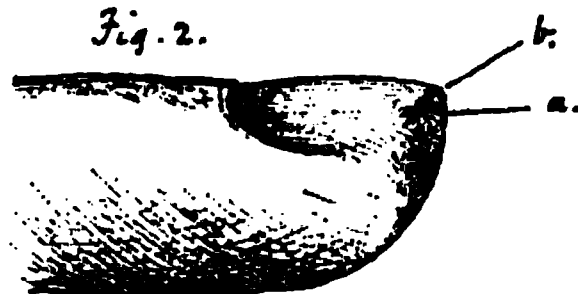


Fig. 3.

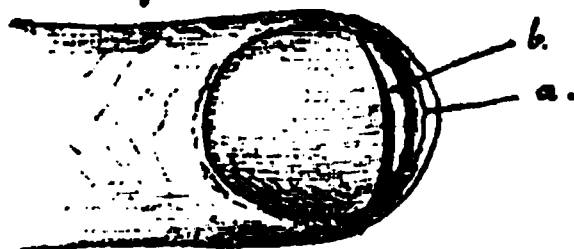


Fig. 1. Condition of the nails at birth.

Fig. 2. Nail cut at seven days. *a*, *b*, the lines of cut.

Fig. 3. Nail at end of fourteen days. *a*, ragged margin of separation; *b*, part of the nail breaking away.

The figures are all drawn about twice the natural size.

separating more and more from the subjacent epidermis, becoming white from the presence of air underneath it, and breaking away from the nail at the pale margin already mentioned as corresponding to the edge of a normal nail (see fig. 3).

At the end of a month all the nails presented very much the normal appearance, except that the epidermis at the extremities of the margin of the nail was a good deal ragged along the line of detachment from the receding nail. The sides of the

nail had also become fairly well marked off from the epidermis, so that the curvilinear groove could be traced forwards to its usual termination. Later on, the nails and neighbouring epidermis became perfectly normal, and nothing remained to show that any abnormal condition had ever been present. There was only one other peculiarity, not an uncommon one, which appeared on the top of the nail near the root, and this was the presence of a thick layer of eponychium, which became thinner, and disappeared altogether as it was traced forwards on the nail.

The toes showed none of this abnormal appearance, with the exception of the great toes, which showed it in a slight degree.

The explanation of this condition appears to be as follows. Usually the function of nail production is limited to the *stratum lucidum* of that part of the finger corresponding to the nail-bed; but in this instance it would appear that the *stratum lucidum* of the tip and sides of the finger also became differentiated into nail, and that the usual breach of continuity of the true nail, with the *stratum lucidum* adjoining it, which usually occurs after the end of the fifth month of intra-uterine life,¹ and results in the formation of a free margin to the nail, did not take place till some time after birth, and then it occurred at the free margin of the abnormal nail. After birth the cells of the *stratum lucidum* in the abnormal nail ceased to be formed into nail, and the normal *stratum corneum* began to appear under the nail substance that was being shed.

¹ Quain's *Anatomy*, tenth edition, vol. i. part 2, p. 419. Cf. MacAlister's *Text-Book of Human Anatomy*, p. 277.

**A RESEARCH INTO THE NATURE AND ACTION OF
THE ENZYMES PRODUCED BY THE BACTERIA.**
By ALLAN MACFADYEN, M.D., B.Sc. (Ed.), *Grocers' Research
Scholar.*

THE researches of Nencki, Brieger, Drechsel, and others have greatly advanced our knowledge respecting the composition of proteid bodies. How great the advance has been will be seen by anyone comparing their researches with the earlier investigations of Liebig, Hlasiwetz, and Schutzenberger. The data obtained are, however, not yet sufficient to enable one to formulate a satisfactory hypothesis with regard to the constitution of proteids. The varied nature of the bodies that arise from the disintegration of proteids indicates how complex their chemical structure must be. The proteid molecule is itself a "complex" of groups of atoms. These groups yield different decomposition products, as *e.g.* Leucin, Indol, Skatol, Methylmercaptan, &c. Chemical research has not yet exhausted the number of these groups or of their derivatives. The chemical structure of the proteids of the living cell is still more complex. Of their properties we know something, of their constitution nothing or next to nothing. These proteids have, however, certain marked characteristics which differentiate them from the metabolic products of the cell itself. The Enzymes are the most familiar example of this group of proteids. In these bodies the atoms of the proteid molecule have undergone a change in position. This may be expressed by saying that they have passed from a stable to an unstable condition. If we consider proteids like the peptones we find that they are stable bodies. Heat, light, &c., do not change their properties; their atoms seem to be in a state of rest. It is different with the enzymes. By the action of heat, light, acids, &c., they lose in part or wholly their characteristic features, and pass from an unstable to a stable modification. They have therefore been termed by the chemist "groups in motion" on account of their close resemblance in

molecular constitution to unstable organic compounds of an aldehyde nature. The enzymes thus share the susceptibility of the protoplasm that produces them to the action of external agents.

As already stated, the most familiar examples of these unstable albumens are the enzymes. Recent bacteriological research has, however, made us acquainted with a group of bodies to which the name of Toxalbumens has been given. Though only a few have as yet been isolated, their number is probably large. The toxalbumens, as regards their properties, have much in common with the enzymes. Just as heat, light, acids, &c. weaken or destroy the ferment action of the enzymes, so do the same agents weaken or destroy the toxic action of the toxalbumens. The toxalbumens are therefore unstable bodies. Like the enzymes they are soluble bodies, and can be precipitated out of their solutions by alcohol. The continued action of alcohol weakens or destroys their poisonous properties—*e.g.*, the toxalbumens of diphtheria and tetanus. The enzymes are innocuous in the digestive tract; they are toxic when injected subcutaneously. The toxalbumens behave in the same way.

The toxalbumens and the enzymes have therefore many points in common, and they are probably closely related in constitution.

It is now generally accepted as proved that the unicellular organisms produce enzymes. It seemed probable to the writer that the study of the formation of these enzymes would also throw light on the mode of production of the toxalbumens. Further, that the methods found best adapted for the demonstration of the action of the enzymes would be the most suitable to use for the study of the toxalbumens. An answer might also be found to an important question: Are the toxalbumens true proteids formed within the bacterial cell itself? I do not refer here to the albuminates. This research is confined to the genuine albumens elaborated by the living cell; which stand closest to it in constitution, and cannot be heated above 50° C. for any length of time without losing wholly or in part their characteristic properties. I now proceed to give the results of my experiments. I am greatly indebted to Professor

von Nencki of Berne and Professor Wolffhügel of Göttingen for much kind assistance and advice.

I.

Upon the production of a proteolytic Enzyme by the Bacteria.

The first series of experiments was made with a group of Comma organisms, viz. :—

1. Koch's Comma bacillus of Cholera asiatica.
2. Deneke's cheese spirillum.
3. Vibrio Metschnikoff.
4. Finkler and Prior's spirillum.

These micro-organisms are convenient to work with, as a comparatively low heat kills them. It is thus possible to sterilise cultures of these organisms at a temperature below 100° C. without completely destroying the ferment action of the fluid. Four series of experiments were made.

- A. With gelatine cultures.
- B. With simple meat-broth cultures.
- C. With peptone meat-broth cultures.
- D. With extracts of the bacteria.

A. Experiments with Gelatine Cultures.

Pure cultures of the above-mentioned bacteria were made in 10% gelatine. These were kept in the incubator at 20° C. for 7–10 days. The tubes were then sterilised in the water-bath at 60°–65° C. for $\frac{1}{2}$ to $\frac{3}{4}$ of an hour. A series of tubes containing 10 c.c. of sterile 10% and 7% gelatine respectively were liquefied, and a few crystals of menthol added. To each of these tubes were added 2 c.c. or 1 c.c. of the sterilised gelatine cultures of the bacteria. They were then placed in the incubator at 39° C. along with control tubes of 10%, 7%, and 5% gelatine. The inoculated and control tubes were taken out of the incubator at intervals of 24 hours. The gelatine was then cooled down, and kept in a cool place to see if any restiffening took place, or if it remained liquid. Sterile gelatine was also inoculated from the tubes in order to make sure that no living bacteria were present.

The experiments gave the following results :—

Series 1.—2 c.c. of the sterilised gelatine cultures of the bacteria

(7-10 days growth) added to 10 c.c. of 10% gelatine and 7% gelatine.

Day Examined.	10% Gelatine.				7% Gelatine.			
	1	2	3	4	1	2	3	4
1. Cholera, . . .		+	+	+		+	++	
2. Deneke, . . .		+	+	+		+	++	
3. Metschnikoff, . .		+	+	+	+	++		
4. Finkler and Prior, . .		+	+	++	++			

Series 2.—1 c.c. of the sterilised gelatine culture of the bacteria (7-10 days growth) added to 10 c.c. of 10% and 7% gelatine.

Day Examined.	10% Gelatine.				7% Gelatine.			
	1	2	3	4	1	2	3	4
1. Cholera, . . .			+	+			+	++
2. Deneke, . . .			+	+			+	++
3. Metschnikoff, . .		+	+	+			++	
4. Finkler and Prior, . .		+	+	++	+	++		

+ = partial liquefaction of the gelatine.
++ = complete liquefaction of the gelatine.

Series 3.—2 c.c. of the sterilised gelatine cultures of the bacteria (4-6 weeks old) added to 10 c.c. of 10% and 7% gelatine.

It will not be necessary to tabulate the results of these experiments. Only the sterilised gelatine cultures of the Metschnikoff and Finkler and Prior organisms produced any distinct liquefaction of the fresh gelatine. The liquefaction also was after four days partial and not complete.

Series 4.—2-5 c.c. of the sterilised gelatine cultures of the bacteria (7-10 days growth) were added to *Fibrin*.

After four days there was no apparent disintegration of the fibrin by the Cholera and Deneke cultures. The Metschnikoff and Finkler and Prior cultures produced a partial disintegration.

These experiments lead one to the following conclusions :—
The bacteria which liquefy gelatine do so by means of a ferment-

like body or enzyme which is capable of exercising its liquefying power on gelatine apart from the cells that produced it. The *sterilised* cultures of the bacteria liquefied fresh gelatine. This fact had already been proved by the researches of Sternberg, Bitter, Lauder Brunton and the writer, and more recently by Fermi. The above experiments confirm therefore the results obtained by these observers. I may, however, mention here that *boiled* gelatine cultures of the bacteria did not liquefy fresh gelatine. The liquefaction was not, therefore, due to the action of any acid. The boiling of the cultures destroyed not only the bacteria, but also the ferment produced by them.

With regard to the liquefying power of the sterilised cultures of the bacteria on gelatine, I found that the most active were the Metschnikoff and Finkler and Prior cultures. The latter, in their turn, had a more energetic action than the Metschnikoff cultures, and were the only ones able to liquefy completely 10% gelatine.

A complete liquefaction of 7% gelatine was produced by sterile cultures of all four organisms, but here again the Metschnikoff and Finkler and Prior cultures had a more energetic action than the Deneke and Cholera. As regards liquefying power on gelatine they stood as follows:—1, Finkler and Prior; 2, Metschnikoff; 3, Cholera; 4, Deneke.

The *old* cultures of the organisms either did not liquefy gelatine, or their action was very feeble. After 4–6 weeks the Cholera and Deneke cultures did not liquefy gelatine. The Metschnikoff and Finkler and Prior cultures showed a very faint action. In these old cultures the metabolic products of the bacteria had probably weakened or destroyed the ferment produced by the cells. Finally, the action on fibrin was very feeble.

The experiments made to determine the production of enzymes by the bacteria have in most cases been carried out with gelatine cultures of the micro-organisms. The method, however, does not give completely satisfactory results. The action on fresh gelatine is often only partial or very slow, whilst on fibrin it sinks to a minimum. The gelatine cultures seem to contain very little of the proteolytic enzyme. It is probable that in a highly nutrient medium like peptone gelatine the bacteria secrete

very little of the enzyme. There is so much easily assimilated nutriment present that the bacteria are able to live without any "struggle for existence" on their part. In such a rich soil the amount of food is far in excess of the requirements of the bacteria, and there is less necessity for an active secretion of their ferment. Further, in a solid medium less of the enzyme passes out of the cells by simple solution than in a fluid medium.

The ferment, too, is mixed with the various metabolic products of the gelatine, which tend to weaken its action. The old gelatine cultures of the bacteria had little or no liquefying power on fresh gelatine. The above factors would explain the relatively small effect of the sterile liquefied gelatine cultures on 10% gelatine, and the feeble action on fibrin. It is probably mainly conditions of nutrition that determine the amount of the ferment secreted by the bacteria.

B. *Experiments with Simple Meat-Broth Cultures.*

The usual meat infusion was used, i.e., the broth obtained by adding to 1 lb. of beef one litre of water.

To the infusion $\frac{1}{2}$ per cent. of sodic chloride was added, and the fluid was rendered faintly alkaline with carbonate of soda.

Flasks containing 100 c.c. of this broth were inoculated from cultures of the four common organisms, and placed in the incubator at 39° C. (In the case of Deneke's spirillum, the optimum temperature was 30° C.) On the third or fourth day the broth cultures were transferred to test-tubes, and sterilised at 60°–65° C. in the water-bath, i.e., they were treated in exactly the same way as the gelatine cultures.

I will here detail only the experiments with 10% gelatine and with fibrin, as they will amply illustrate the results obtained.

Series 1.—2 c.c. of the sterile meat-broth cultures of the bacteria, added to 10 c.c. of 10% gelatine + menthol.

Day Examined.	1	2	3
1. Cholera,		+	++
2. Deneke,		+	++
3. Metschnikoff,		+	++
4. Finkler and Prior,	+	++	

+ = partial liquefaction of gelatine.
++ = complete liquefaction of gelatine.

Series 2.—5 c.c. of the sterile meat-broth cultures of the bacteria, added to fibrin + menthol.

Results:—

- | | |
|-------------------------------|---|
| 1. <i>Cholera</i> , | Complete disintegration of the fibrin on the 5th day. |
| 2. <i>Deneke</i> , | " " " 5th day. |
| 3. <i>Metschnikoff</i> , | " " " 4th day. |
| 4. <i>Finkler and Prior</i> , | " " " 3rd day. |

In control tubes containing 5 c.c. of fresh broth + fibrin and menthol, the fibrin remained unchanged.

Fresh gelatine was also inoculated from the tubes containing the sterilised meat-broth cultures + fibrin or gelatine. In neither case did any bacteria grow in the control tubes.

Series 3.—The meat-broth cultures of the bacteria were also concentrated to one-half of their volume in Brieger's vacuum distilling apparatus. Of this concentrated fluid 5 c.c. was added after sterilisation at 60°–65° C. to fibrin + menthol.

Results:—The *Cholera* and *Deneke* cultures, treated in this fashion, digested the fibrin on the fourth day. The *Metschnikoff* and *Finkler and Prior* cultures digested the fibrin on the third day.

The digestive action on fibrin was therefore a little stronger in the concentrated than in the unconcentrated meat-broth cultures.

Series 4.—A series of experiments made with *Eggalbumen*.

The results of these experiments may be mentioned here, as they serve to bring out one interesting point.

5 c.c. of the sterilised and unconcentrated meat-broth cultures of the bacteria were added to coagulated eggalbumen + thymol. The tubes were placed in the incubator at 39° C.

The *Cholera* and *Metschnikoff* cultures disintegrated the eggalbumen on the *second* or *third* day.

The *Deneke* and *Finkler and Prior* cultures only disintegrated the eggalbumen on the *fourth* or *fifth* day. The ferment action of the *Cholera* and *Metschnikoff* cultures was therefore more energetic on eggalbumen than on fibrin, and exceeded that of the *Deneke* and *Finkler and Prior* cultures. On the other hand, the *Finkler and Prior* cultures had a more energetic action on fibrin than any of the others. Thus the proteolytic action of the enzymes produced by the bacteria varies on different forms of albumens. The proteolytic action may be weak on fibrin, and yet strong on eggalbumen. The reverse also holds true. The ferment action of the bacteria varies, therefore, with the nature of the soil in which they grow.

C. *Experiments with Peptone Meat-Broth Cultures.*

2% of peptone and 0.5% of sodic chloride were added to the meat infusion, and the fluid made faintly alkaline with carbonate of soda.

Flasks containing 100 c.c. of this culture fluid were inoculated from pure cultures of the bacteria, and placed in the incubator at

39° C. On the third or fourth day the peptone broth cultures were transferred to test-tubes, and sterilised at 60°–65° C. in a water-bath. The ferment action of these sterilised cultures was tested on gelatine and on fibrin.

Series 1.—2 c.c. of the sterilised peptone meat-broth cultures of the bacteria, added to 10 c.c. of 10% gelatine + menthol.

Results :—

Day Examined.	1	2	3	4
1. Cholera,		+	+	++
2. Deneke,		+	+	+
3. Metschnikoff, . . .		+	+	++
4. Finkler and Prior, . .		+	+	++

+ = partial liquefaction of gelatine.
++ = complete liquefaction of gelatine.

Series 2.—5 c.c. of the sterilised peptone meat-broth cultures of the bacteria added to fibrin + menthol.

Results :—

1. Cholera,

2. Deneke,

3. Metschnikoff,

4. Finkler and Prior,
- {

}

{

}
- No complete disintegration of fibrin on the *fifth* day.

Complete disintegration of fibrin on the *fifth* day.

The experiments detailed under headings B. and C. lead one to the following conclusions:—

The simple meat-broth cultures of the bacteria yield a more active proteolytic enzyme than the gelatine cultures. There is more of the enzyme present in the simple meat-broth than in the gelatine. Further, the simple meat-broth cultures have a more energetic action on fibrin than the richer and more nutrient broth which had been rendered so by the addition of 2% of peptone. The amount of the soluble ferment albumen secreted by the cells is determined by the nutritive requirements of the micro-organisms. Less is secreted in a rich soil than in a poor soil, where a greater effort has to be made for nutrition. The luxuriance of the bacterial growth is no criterion as to the amount of the enzyme present in the culture fluid. The growth of the bacteria was more abundant in the peptone

broth than in the simple meat-broth, yet the latter had a more energetic ferment action.

When a micro-organism is placed under conditions inimical to its growth, more of the soluble cell proteids pass over into the surrounding medium than is the case where the conditions are favourable. This fact would have great pathological interest if we can prove that these unstable soluble proteids of the bacterial cells possess toxic properties. I will detail later on some animal experiments with reference to this point.

The above experiments have shown that the best medium for the productions of these soluble cell proteids is simple meat-broth, and that with it the best results are to be obtained.

There is evidently only a fractional amount of the enzymes present in the gelatine cultures of the bacteria. A much larger amount is present in the meat-broth cultures, though the amount is also probably fractional. The enzymes being soluble bodies, would it not be possible to extract them directly from the bacterial cells? If successful, this would undoubtedly be the best method. We would obtain the bacteria as free as possible from their metabolic products; and the extracts would contain the soluble cell proteids in a purer form.

The following experiments were made with the view of elucidating this point.

D. Experiments with Extracts of the Bacteria.

A small quantity of nutritive Agar-Agar was placed in Erlenmeyer flasks of 200–250 c.c. capacity. The Agar-Agar, after sterilisation, was allowed to stiffen on one side of the flask. In this way a large surface was obtained for inoculation with the bacteria. The Agar was inoculated from pure cultures of the Cholera; Deneke; Metschnikoff and Finkler and Prior organisms. The bacteria, by means of a platinum wire, were well distributed over the whole surface of the Agar. The flasks were then placed in the incubator at 39° C., with the exception of the Deneke cultures, which grew best at 30° C.

In this way a large surface growth of the bacteria was obtained in two to three days. The growth was then scraped off with a blunt, sterilised platinum spatula, and transferred to small Erlenmeyer flasks or to test-tubes.

The following methods of extraction were tested.

(1) Extraction with Chloroform Water.

Chloroform water was added to the bacteria, and the tubes or flasks placed in the incubator at 39° C. for 3–4 days. They were

then kept at 30° C. for three days longer. At the end of that time they were taken for the experiments. It was found that the bacteria settled at the bottom of the tube or flask, and the supernatant fluid could thus be removed with a pipette from the deposit.

5 c.c. of the watery extract were added to fibrin or eggalbumen. I found that the digestive action on these proteids was very slight, and was not to be compared with the ferment action of the meat-broth cultures of the same bacteria. It was evident that simple extraction with water alone would not suffice. These experiments were therefore abandoned.

(2) *Extraction with pure undiluted Glycerine.*

These experiments also did not give any satisfactory results.

(3) *Extraction with Glycerine + Water.*

It was found that this method gave the best results, and that the best concentration to use was a 40% solution of glycerine in water. The bacteria were cultivated on agar in the manner already described. On the third or fourth day the growth was scraped off with a platinum spatula, and placed in small Erlenmeyer flasks or in tubes. The 40% glycerine was then added. The bacteria were extracted for four days at 39° C., and for three days at 30° C., altogether one week.

The same bacteria were used as on the previous experiments. I found that the comma organisms were particularly well adapted for extraction with glycerine. For example, the solvent action of the glycerine on Koch's comma bacillus is so great that the organisms disappear almost entirely. The comma micro-organisms would therefore probably yield the best results. If one succeeded at all, it would be with these bacteria. Experiments made with them would furnish data for further researches with other bacteria. For these reasons the first series of experiments was made with the spirilli.

When the remains of the bacteria had settled at the bottom of the tube or flask, the supernatant fluid was removed with a pipette. An advantage of this method is that it obviates the necessity of sterilising the fluid by heating. The glycerine itself has an inimical action on the bacteria, and if one adds a small amount of thymol or menthol the extracts remain absolutely sterile.

The glycerine extracts prepared as above were tested on gelatine, fibrin, and eggalbumen.

I. *Experiments with Gelatine.*

1st Series.—1–2 c.c. of the glycerine extracts of the bacteria were added to 10 c.c. of 7% gelatine in test-tubes, so that the extract formed a layer on the surface of the gelatine. A mark was made on the outside of the tubes at the line of junction between the gelatine and the extract. In this way one could observe if any liquefaction of the gelatine took place from above downwards. I am

indebted to Dr Fermi for this method. The tubes were kept in the incubator at 20° C.

Results :—The amount of liquefaction noted on the fourth day was as follows :—

- | | | | | |
|-----------------------|---|---|---|---|
| 1. Cholera, | . | . | . | $\frac{1}{4}$ inch of gelatine liquefied. |
| 2. Deneke, | . | . | . | $\frac{1}{4}$ inch " " |
| 3. Metschnikoff, | . | . | . | $\frac{1}{2}$ inch " " |
| 4. Finkler and Prior, | . | . | . | $\frac{3}{4}$ inch " " |

2nd Series.—1 c.c. of the glycerine extracts of the bacteria was added to 10 c.c. of 7% gelatine. The tubes were kept at 30° C. and 39° C. On the third day the glycerine extracts of the bacteria had completely liquefied the gelatine. In the case of Finkler and Prior the gelatine was liquefied on the second day. The results were the same when the tubes were kept at a temperature of 39° C. or 30° C.

II. Experiments with Fibrin.

3–5 c.c. of the glycerine extracts of the bacteria were added to fibrin + menthol. The tubes were kept in the incubator at 39° C.

Results :—

- | | | |
|-----------------------|---|---|
| 1. Cholera, | { | Complete disintegration of the fibrin on the third to fourth day. |
| 2. Deneke, | | |
| 3. Metschnikoff, | " | " on the second to third day. |
| 4. Finkler and Prior, | " | " on the second day. |

III. Experiments with Eggalbumen.

3–5 c.c. of the glycerine extract of the bacteria added to eggalbumen + menthol.

Results :—

- | | |
|-----------------------|---|
| 1. Cholera, | Complete disintegration of eggalbumen on second to third day. |
| 2. Deneke, | " " on fourth to fifth day. |
| 3. Metschnikoff, | " " on second to third day. |
| 4. Finkler and Prior, | " " on fourth to fifth day. |

Control inoculations were in all cases made on fresh gelatine, to make sure that the fluids had remained sterile.

These experiments demonstrate that the glycerine extracts of the bacteria contain a proteolytic enzyme which liquefies gelatine and digests fibrin and eggalbumen.

Glycerine extracts which had stood in the laboratory for two months had little or no effect on gelatine, fibrin, or eggalbumen. The proteolytic ferment produced by these bacteria is evidently of a very unstable nature, and when separated from the cells that produce it becomes readily converted into an inactive modification.

Whilst the fresh glycerine extracts had a distinct ferment action, there were variations in the action due to the nature of the soil. Thus the Cholera and Metschnikoff extracts had a more energetic action on eggalbumen than the extracts of the Finkler and Prior spirillum. On the other hand, the Finkler and Prior extract had a more energetic action on fibrin than either the Cholera or Metschnikoff extract.

To sum up shortly the results of these experiments:—

1. The fresh glycerine extracts made from young agar cultures of the Cholera, Deneke, Metschnikoff and Finkler and Prior spirilli contain an enzyme which, like trypsin, is capable of digesting proteids.

2. The enzyme, when extracted from the cells that produce it, does not retain its ferment action for any length of time. At the end of two months the glycerine extracts had no action on proteids.

3. The ferment action of the glycerine extracts varies according to the nature of the soil, as the experiments with fibrin and eggalbumen prove.

The filtering of the glycerine extracts through biscuit porcelain cells has presented difficulties which I have not yet satisfactorily overcome.

In a second paper the results will be given of experiments made with the glycerine extracts of anthrax and other pathogenic bacteria.

II.

Upon the presence of a diastatic Enzyme in the Glycerine extracts of the Bacteria.

It was next of interest to ascertain if the glycerine extracts of the bacteria contained a *diastatic enzyme*.

The action of pure cultures of the bacteria on starch was first tested.

A starch paste was made by boiling 1·5–2% of starch in water. This paste was poured whilst still hot into test-tubes, and sterilised in the usual way. On cooling, some starch flocculi settled at the bottom of the tubes: these flocculi enable one to gauge in a rough fashion the action of the bacteria on the starch. The first change undergone by the starch is its conversion into a soluble form. If one shakes a tube containing sterile starch paste, the flocculi do *not* disappear: on the other hand, if one shakes a tube in which a micro-organism is diastasing the starch, the flocculi disappear and pass

completely into solution. Further, the paste loses its milky appearance, it becomes watery and transparent. The control tube, on the other hand, remains viscid, milky, and opaque. In this fashion one can note with what rapidity the starch is being diastased.

The starch paste was inoculated from pure cultures of the Cholera, Deneke, Metschnikoff, and Finkler spirilli. It is an advantage to add at the same time a few drops of meat-broth. The tubes were kept at 39° C. or 30° C.

Results:—

1. *Cholera*, Starch flocculi disappear on second day.
2. *Deneke*, „ „ on third day.
3. *Metschnikoff*, „ „ on third day.
4. *Finkler and Prior*, Starch flocculi still present on fifth day.

One sees from these preliminary experiments that the first three microbes had an action on the starch, and that the fourth produced no apparent change. The starch cultures were next tested chemically. If one wishes to compare the results obtained with the different bacteria, other tests must be employed besides Fehling's. It is then important to ascertain not only if sugar is present, but if the starch has been wholly or partially diastased by the bacterium.

The method used in this research was based on the successive changes starch undergoes when being converted into sugar. These are as follows:—

1. *Original starch*,
2. *Soluble starch* (amylo dextrin) } + Iodine = blue.
3. *Dextrines*, Erythro-dextrin + Iodine = violet and red.
- Achroo-dextrin } + Iodine = O.
- Malto-dextrin }
4. *Maltose*, { Reduces Fehling's solution.
- Does not reduce Barfoed's reagent.
5. *Dextrose*, { Reduces both Fehling's solution and Barfoed's reagent.

Another test employed was found to be very useful,—viz., the addition of caustic soda to the starch paste. If no yellow coloration is produced, dextrose is not present; if the fluid becomes yellow, either dextrose, maltose, or milk sugar may be present. I found that the intensity of the colour produced by adding caustic soda was always proportional to the amount of reduction of Fehling's solution—i.e., the deeper the tinge of yellow produced, the greater the reduction of Fehling, and *vice versa*.

Barfoed's reagent consists of 1 part of the neutral acetate of copper dissolved in 15 parts of water. To 200 c.c. are added 5 c.c. of a 38% solution of acetic acid.

Results :—Starch paste inoculated from pure cultures of the bacteria.

	Day of Ex-amination.	Caustic Soda.	Iodine.	Fehling.	Barfoed.
1. Cholera.	1	faint yellow	blue	faint reduction	0
	2	deep yellow	violet	distinct reduction	„
	3	orange yellow	red	copious pp.	„
	4	„	0	„	„
2. Deneke.	1	0	blue	0	„
	2	faint yellow	„	faint reduction	„
	3	yellow	violet	distinct reduction	„
	4	„	red	„	„
3. Metschnikoff.	1	0	blue	0	„
	2	yellow	„	distinct reduction	„
	3	„	violet	copious pp.	„
	4	orange yellow	red	„	„
4. Finkler and Prior.	1	0	blue	0	„
	2	0	„	„	„
	3	faint yellow	„	„	„
	4	„	„	faint reduction (?)	„

The tubes were kept at a temperature of 30° and 39° C.

From these experiments it will be seen that the Cholera, Deneke, and Metschnikoff organisms diastased the starch. The action of the Finkler and Prior spirillum was almost *nil*; on the fourth day there was only a faint reduction of Fehling's solution. The Cholera spirillum had the most active diastatic action; its action was more rapid and energetic than that of the Deneke or Metschnikoff organisms. As already stated, the action of the Finkler spirillum was almost *nil* on the starch. The Finkler spirillum which had the strongest action on gelatine, had the weakest action on starch. On the other hand, the Cholera spirillum, which had the weakest liquefying power on gelatine, displayed the strongest diastatic action on starch. The action on the starch was marked at the end of twenty-four hours, when Fehling's solution was reduced. The starch cultures of the Deneke and Metschnikoff organisms first reduced Fehling's solution after forty-eight hours. On the fourth day the starch

had disappeared altogether in the Cholera cultures, and no reaction was given with iodine. None of the other organisms completely diastased the starch. The experiments I have made lead me to the conclusion that the *diastatic* action of the Cholera spirillum greatly exceeds its proteolytic action. In other words, its ferment action is more marked on carbohydrates than on proteids. If we compare the ferment action of the Finkler with that of the Cholera spirillum, we may say that the characteristic enzyme in the former case is a proteolytic, in the latter a diastatic one.

The Cholera spirillum is thus specially adapted for growth in a carbohydrate soil. The presence of carbohydrates will rather favour than hinder its growth. If a carbohydrate food such as rice is present in the digestive tract, it will furnish a most favourable nidus for the Cholera organism. In such a soil it will rapidly multiply, and set up at the same time a most active fermentation.

The action of the glycerine extracts of the bacteria on starch paste was next tested.

The glycerine used had no reducing action on Fehling's solution, nor had it any action on the starch.

1 c.c. of the sterile glycerine extracts of the bacteria was added to the starch paste, with the following results :—

	Day of Examina- tion.	Caustic Sod.	Iodine.	Fehling.	Barfoed.
1. Cholera.	1	0	Blue	0	0
	2	Faint Yellow	Blue	Reduction	„
	3	Yellow	Violet	do.	„
	4	do.	Red	do.	„
2. Deneke.	1	0	Blue	0	„
	2	Faint Yellow	do.	0	„
	3	do.	do.	Reduction	„
	4	Yellow	do.	do.	„
3. Metschnikoff.	1	0	Blue	0	„
	2	Faint Yellow	Violet	0	„
	3	Yellow	do.	Reduction	„
	4	do.	do.	do.	„
4. Finkler and Prior.	1-4	0	0	0	„

It will be seen that the glycerine extract of Finkler's spirillum had no action on the starch. On the other hand, the extracts of the Cholera, Deneke, and Metschnikoff spirilli diastased the starch. The Cholera extract was the most active. The starch

paste to which it was added reduced Fehling's solution on the second day. The negative results with Barfoed's reagent indicate that the sugar produced by the bacteria is probably of the nature of a maltose.

These experiments prove that the glycerine extracts of the bacteria which diastase starch contain an enzyme which, when separated from the cells that produce it, is capable of converting starch into sugar. Further, it was already shown that the glycerine extracts of the same bacteria contain also a proteolytic enzyme.

Experiments were also made with a view of determining the presence or absence of a *milk curdling ferment* in the glycerine extracts of the bacteria. These experiments are still being carried on, but the results are not yet of a sufficiently definite character.

It is of great importance to investigate the influence of the bacteria on the *coagulating power* of the blood. This question has also engaged the attention of the writer, and will be dealt with in a future paper. One interesting point may, however, be mentioned here.

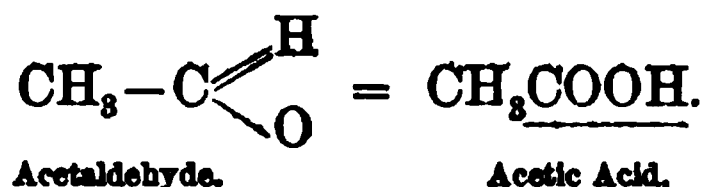
A nutrient medium was prepared, consisting of blood serum, glycerine, and water. This mixture did not coagulate on boiling. It was inoculated from pure cultures of the Cholera and the Finkler spirillum. The organisms grew well in this soil. On the third day after inoculation there was a complete coagulation of the blood serum in the tubes inoculated with the Cholera spirillum. There was no coagulation in the tubes inoculated with Finkler's spirillum. This striking difference in the action of these two organisms on the blood serum opened up a fresh line of inquiry, and when sufficiently advanced its results will be given.

*The action of the Glycerine extracts of the Bacteria on
Loew's Reagent.*

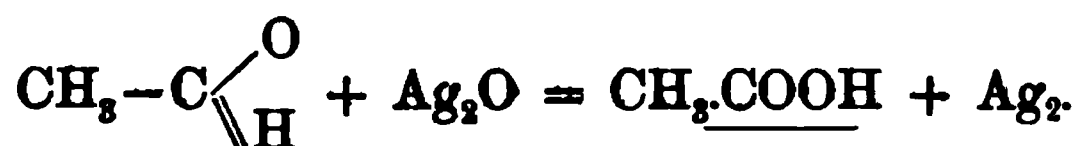
In the introduction to this paper mention was made of certain striking differences that exist between the proteids of the living cell, and other forms of albumens such as the Peptones. The latter are stable bodies. By the action of heat, light, &c. they do not change their properties. The Enzymes, on the other

hand, are unstable proteids. Heat, light, acids, and alkalies weaken and finally destroy their characteristic properties. In this respect they share the sensitiveness of the protoplasm itself to external agents. The toxalbumens produced by the bacteria have also an unstable constitution. They are readily transformed into an inactive modification, and lose their toxic properties. The chemical structure of the unstable proteids differ, therefore, from that of the stable. What that difference really is, remains a matter of conjecture. The distinction may consist in a different grouping of the atoms in their molecule. As regards their unstable chemical constitution, an analogy is to be found in certain organic chemical compounds. The aldehydes, for instance, are very unstable bodies. The aldehydes contain

the aldehyde group $\text{C} \begin{smallmatrix} \text{H} \\ \diagup \\ \diagdown \\ \text{O} \end{smallmatrix}$. They easily undergo oxidation on simple exposure to the air,—*e.g.*,



Further, they easily reduce metallic oxides, especially the oxide of silver, in alkaline solution.



Nencki also found that very dilute alkaline solutions of albumens absorbed oxygen slowly from the air. Loew's well-known researches prove that the living protoplasm of certain Algæ reduces a dilute alkaline solution of silver. In this respect the chemical structure of the albumens of the living cell may resemble that of those organic bodies which contain in their molecule the unstable and easily oxidised aldehyde group

$\text{C} \begin{smallmatrix} \text{H} \\ \diagup \\ \diagdown \\ \text{O} \end{smallmatrix}$. The dead protoplasm does *not* reduce the oxide of silver.

The question suggested itself—Have the active ferments produced by the bacteria a similar action on the oxide of silver to that of the living protoplasm?

The glycerine extracts of the bacteria were accordingly tested with Loew's reagent. It was possible that Loew's reagent might be a valuable test for ascertaining the presence or absence of an active ferment in the glycerine extracts of a micro-organism.

The fresh glycerine extracts of the Cholera, Deneke, Metschnikoff, and Finkler spirilli were added to Loew's reagent along with a small quantity of menthol. The glycerine and the menthol did not reduce the silver solution. The fresh glycerine extracts of the Cholera spirillum and the vibrio Metschnikoff produced a distinct reduction of the oxide of silver. The extracts of the Deneke and Finkler spirilli also reduced the silver solution, though not so actively as was the case with the two former organisms. The tubes during the experiments were protected from the action of light.

The active reduction of the silver by the extracts of the Cholera spirillum and vibrio Metschnikoff might be due to the presence of a larger amount of the soluble cell proteids in the extracts than was the case in the extracts of the Deneke and the Finkler spirillum.

A large number of experiments will have to be made with other micro-organisms before one is in a position to estimate the value of this test. These experiments will decide if the reducing action on silver is a general one, or confined to certain bacteria.

Loew's Reagent is prepared as follows:—

No. I. 13 c.c. of a solution of Potash—1.333 spec. gr.
10 c.c. of Ammonia—0.96 spec. gr.
77 c.c. of Water.

No. II. 1 per cent. solution of Nitrate of Silver.

Immediately before use 1 c.c. of No. I. is mixed with 1 c.c. of No. II. and diluted to a litre.

The glycerine extracts of the bacteria do not, of course, contain the active ferments produced by the bacteria in a pure form. They are mixed with other soluble albumens of the cell protoplasm, of whose nature we as yet know little.

The glycerine extracts yielded precipitates with alcohol; ammonium sulphate; acetic acid and ferrocyanide of potassium. Also with acetic acid and sodic chloride. The glycerine extracts therefore contain a group of bodies of an albuminose nature. The

active ferments adhere to the alcoholic precipitates, though the alcohol weakens their action. The alcoholic precipitates produced a partial liquefaction of gelatine, and had also a feeble diastatic action on starch. The writer is still engaged upon the chemical examination of these precipitates.

Animal Experiments.

The action of the glycerine extracts on animals was next tested.

I will here detail experiments made with the extracts of the Cholera spirillum and the vibrio Metschnikoff.

Glycerine extracts not more than a fortnight old were used.

$\frac{1}{2}$ c.c. of the glycerine extract was diluted to 1 c.c. with water, and injected into a guinea-pig under the skin of the abdomen.

In both cases the result was a marked and rapid fall in temperature of the animals, as will be seen from the following Tables.

I.

Glycerine Extract of Cholera Spirillum.

The injection was made at 11.15 A.M.

<i>Time</i>	<i>11.15 A.M.</i>	<i>Temperature</i>	<i>98.4° F.</i>
„	11.30 „		97.9
„	11.45 „		96.9
„	12.15 P.M.		95.8
„	12.30 „		94.8
„	12.45 „		95
„	2 „		95.6
„	2.25 „		95.6
„	3 „		95.6
„	4 „		95.6
„	5 „		95.8
„	6 „		96

On the next day the temperature of the animal was again normal. The animal did not die. The marked symptom was the great fall in temperature produced. One hour and a half after the injection the temperature had fallen to 95° F., and remained subnormal for seven to eight hours. After twenty-four hours it had risen again to 98.4° F. The glycerine extract of the Cholera spirillum produced therefore in guinea-pigs a characteristic symptom of cholera asiatica in man.

II.

Glycerine Extract of Vibrio Metschnikoff.

The injection was made at 11 A.M.

Time	11 A.M.	Temperature	98·4° F.
11.15	„	97·2	
11.30	„	97·2	
11.45	„	96	
12.15	P.M.	96·4	
12.45	„	97·2	
1.15	„	97	
2.30	„	98·4	

Here also there was a marked and rapid fall in temperature. The minimum was 96° F., as compared with 95° F. in the Cholera experiments. The recovery also was more rapid, and three and a half hours after injection the temperature had risen to the normal.

The glycerine extracts of the Cholera and Metschnikoff spirilli therefore contain soluble cell proteids which have a toxic effect on animals. These toxalbumens, if not identical with the ferments produced by the bacteria, are closely related to them in constitution. They are in any case, like the ferments, *intra-cellular* products. They are, further, rapidly absorbed when injected into animals; producing an almost immediate toxic effect.

The results obtained with the Cholera and Metschnikoff spirillum have led me to extend these experiments to anthrax and other pathogenic bacteria. These investigations will be communicated in a further paper. The toxic effects of the glycerine extracts of the bacteria, and of the precipitates obtained from them, will then be fully gone into.

I will conclude this paper with a brief summary of the results of the above researches:—

1. The bacteria which liquefy gelatine do so by means of a soluble ferment or enzyme. The action of the enzyme on gelatine can be demonstrated apart from the cells that produced it.

2. The amount of this proteolytic enzyme secreted varies according to the nature of the soil. The amount present in gelatine cultures of the bacteria is relatively small. The amount secreted in simple meat-broth cultures is much larger.

3. It is probably conditions of nutrition which regulate the amount of enzyme secreted, as the simple meat-broth cultures had a more active ferment action than the gelatine or peptone meat-broth cultures.

4. Simple meat-broth is the best medium for the production of these soluble ferments.

5. The action of the ferments varies with the nature of the soil. The Cholera enzyme had a more energetic action on eggalbumen than on fibrin. The ferment produced by Finkler's spirillum had an opposite effect.

6. The glycerine extracts of the bacteria also contain the active ferments.

7. The glycerine extracts contain not only a proteolytic, but also a diastatic enzyme which converts starch into sugar. The soluble cell proteids can therefore be extracted from the cells by means of glycerine, and their action demonstrated.

8. The most active enzyme produced by the Cholera spirillum is a diastatic, and not a proteolytic.

9. The glycerine extracts of the spirilli reduce Loew's reagent, in this way acting like the protoplasm of the living cell.

10. The glycerine extracts which contain the active ferments of the bacteria, possess also toxic properties. The soluble cell proteids which possess these toxic properties are closely related in constitution to the ferments, and may be identical with them, or a modification of them. The account of these investigations will be continued in a second paper.

REPORT ON RECENT TERATOLOGICAL LITERATURE. By
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IN commencing this second Report on Teratological Literature, it may be as well to state, for the sake of avoiding criticism and misunderstanding, that limitations of time and space forbid the mention of many papers otherwise worthy of attention. I have, therefore, preferred to deal chiefly with those which are least accessible to English workers,—a decision which will account for the exclusion of various articles and cases which have appeared in periodicals published in this country.

GENERAL.—In an important paper, His (I.) refers to the valuable information which may be obtained from the examination of a number of early abortions, some of which are the subject of malformations, using that term in the narrower sense, but the greater number of which belong to the class of imperfect, or “abortive,” forms. These he divides into three groups:—1. *nodular* embryos, where a more or less rounded body, attached to the chorion, is the only remains of the embryo; 2. *cylindrical*, where the embryo exists as a more or less sack-shaped structure, with a varying amount of obliteration of the normal external form; 3. *contorted*, where the embryo is bent in one or more irregular ways. To these abortive embryos the author in question had already drawn attention (1), and similar malformed embryos are the subject of a paper by Kollmann (2); but a further examination of the subject has led the author to the following conclusions: (1) embryos which for some reason have remained stationary in their development may, without decomposition or absorption, remain within their membranes for weeks or even for months; (2) the first change which manifests itself in abortive embryos is a marked swelling of the central nervous organs, as a consequence of which more or less remarkable transformations of the head occur; (3) very shortly afterwards an invasion of the different tissues by wandering cells takes place; the original limits of the organs thus become obliterated, and though their cells remain visible for some time, they appear finally to become broken up; (4) the appearances visible externally as an index of the internal changes are—the embryo becomes cloudy and soft, and all the existing surface-markings become less distinct. The author points out that the existence of active wandering cells in the tissues is in no sense a proof of the life of the embryo, though the question is still doubtful as to where these cells take origin. Other questions which are raised by an examination of the conditions under consideration are as to why the membranes of such embryos continue to grow and the liquor amnii to increase, and why the embryo does not become decomposed. Again, what are the causes which induce the early death of the embryo?

and are the changes in form of such embryos secondary to their death? or is the abortiveness a consequence of the primitive formation of the embryo at the time of impregnation?

A posthumous paper of Saint-Ange (II.) gives an account of a foetus of the class *Phocomelia*, presenting some points of interest. The placenta had on its uterine surface nine indurated patches, of a nacreous colour, from 1.0 to 4.0 cm. in diameter, and formed by masses of chorionic villi in a state of fibrous degeneration. Each of these was surrounded by a blackish zone of blood, which had become extravasated by rupture of the decidua. There were six toes on each foot, and six digits on each hand. The middle phalanx was only represented by a cartilaginous nodule in the case of all the digits and toes save the pollex and hallux. The bones of the carpus and tarsus, unseparated from one another, formed irregular masses. The two bones of each leg were united to one another. The femora, with the exception of their heads, were almost unformed. The humeri were united to the bones of the forearm. There was a widely patent foramen ovale, and a left superior vena cava opened into the right auricle. There was a cleft palate, and the tongue was very small and fastened down in front to the floor of the mouth by a short frænum. This case having been submitted to Dareste, was pronounced by him to be of special interest, because all instances of similar malformation hitherto recorded have been unaccompanied by defects other than those of the limbs. He considers that all the defects in this case save the sexdigitism, may be explained by an arrest of development. Symington and Thomson (III.) have described a foetus which may be mentioned here, because, although they do not give it that name, their description and the figure attached closely resemble the appearances of a Phocomelous monster. The departures from the normal in the skeleton in this case affected those portions which, formed in cartilage, largely depend for their growth during foetal life upon endochondral ossification, and the cause of the departure was a premature arrest or absence of this process. The condition of the bones is fully described in the paper. The authors are of opinion that the condition is not one of foetal rickets, but are less certain whether it is cretinoid in its nature. It may be noted that Sânger (3) some years ago described a similar foetus, and in his figure represents sections of a rib of the foetus, of rickety bone and of normal bone. He discusses the relation between the condition he describes and that met with in rickets.

Congenital Neoplasmata receive full attention at the hands of Cristiani (IV.), who, at the conclusion of his paper (the exhaustive nature of which may be judged by the fact that the bibliography contains over 700 references), states that all the principal forms of neoplasmata which are observed in the adult may also be met with in the new-born child, that there is no reason to consider that congenital neoplasmata differ in any way from those appearing in after years, and that a certain number of neoplasmata undoubtedly owe their origin to embryonic inclusions, a number probably greater than is usually admitted.

ACARDIAC.—Ross (V.) describes an œdematous acardiac in which the limbs were swollen to three or four times their normal size. The upper part of the body consisted of a rounded mass, which on section showed cavities full of a pale yellow fluid, the connective tissue being also infiltrated with the same. There was no thorax, arms, or head. The abdomen contained two kidneys and an ill-developed intestine, but no liver, spleen, or pancreas. This œdematous condition of acardiacs has been dealt with by Alban Doran (4), and has been accounted for by Abelfeld, by the smallness of calibre of the veins, producing a stasis. Birmingham's observation (5) as to the absence of a thoracic duct in an œdematous foetus (not acardiac) is worthy of note in this connection as possibly pointing to another explanation. A similar acardiac to the one above mentioned is described by Alezais (VI.).

DUPLIOTY.—Virchow (VII.), alluding to the brothers Tocci, shown by him to the Anthropologisches Gesellschaft of Berlin in 1886, showed the skeleton from a case of *Xiphodymia*, pointing out especially the arrangements of the two parallel vertebral columns. He states that the features of these cases prove that these malformations cannot be caused by the union of two already formed bodies, but that the disturbance originating them must occur at a period of embryonic life when the individual parts are not formed. Moreover, that the symmetrical arrangement of the monster shows that the embryonic cell-groups at the time of the disturbance must have been in their original closely connected condition. Burci (VIII.) describes a perineal tumour which he designates *perineoamorphus*. It was removed from a male child aged eight months, was situated just behind the scrotum, and had a maximum diameter of 5 cm. There was no diminution in size on pressure, nor was the tumour apparently connected with the scrotum. It was superficial to the superficial perineal aponeurosis. On section it was observed to contain two nuclei, one on either side, of a yellowish colour, with each of which was connected a thin reddish-yellow cord. On microscopic examination, unstriated muscular fibres were found in the outer part of the tumour. The nuclei were contained in fibrous capsules well supplied with vessels; internally they consisted of a stroma infiltrated with lymphoid cells and forming alveoli, which latter were filled with epithelial cells, the stroma also containing numerous vessels. Each of the cords contained a large vessel and a small one, together with a nerve bundle.

An instance of partial *doubling of the spinal cord* is given by Jacobsohn (IX.). The second portion of cord was found at the left side of the lumbar enlargement. It lost itself in the normal cord above, but below was quite free. It contained at its posterior part a band of grey substance, like that of the posterior cornu, surrounded by transverse white fibres. The cord itself was very asymmetrical, the posterior cornu being absent in the middle and lower parts.

Taruffi (X.) describes two cases of a condition which he names *Syncephalus dilecanus*. The first was a boy aged three years and a half, who had two penes, both with pervious urethræ, through which urine

was simultaneously voided, two scrotal sacs, the right containing two testes and the left one, and two anal orifices through which faeces were evacuated at the same time. The pubic bones were separated from one another by an interval through which the bladder could be felt, pressure upon the organ causing the passage of urine. The pelvis was wider than normal, the bitrochanteric measurement being 0.185 m. (normal av. 0.165), and the bisiliac 0.165 m. (normal av. 0.135). The second case was that of an adult, who would not permit careful examination, but who possessed two penes capable of simultaneous erection. These cases have been classified by Gurlt under the heading of "diphallus," and they illustrate the views expressed by Cleland (6). A further stage in this form of duplicity is met with in cases like that described recently (7), where in a female, besides double genitalia, there were present two additional but diminutive lower extremities. Bertaux (XI.) describes a possibly comparable case in a boy, where, on the right side of the perineal raphe, there was a second anal opening, through which faeces were voided at the same time as through the normal opening. In connection with defects of the anus, attention may be drawn, though the subject has no affinity with that of duplicity, to the congenital *coccygeal fistulae* described by Bilhaut (XII.). These exist in certain persons as a depression of the integument, or as a fissure more or less elongated and deep. They may become obliterated accidentally, may give rise to abscesses, or act in the same manner as a dermoid.

ENCEPHALOCELES.—Burci (XIII.) describes a case of *occipital tumour* in a child aged eight months, which gradually increased from the size of a nut to that of an orange. After death it was found to be a hydrencephalocele protruding through the centre of the occipital bone. The third and lateral ventricles were dilated, as was the fourth, with which the sac directly communicated. The valve of Vieussens and the middle lobe of the cerebellum were absent. Calori (XIV.) gives a very full account of a foetus, affected also with a mesial hare-lip and cleft-palate, from whose forehead protruded a tumour 69 mm. in length, 45 mm. in breadth, and 210 mm. at its maximum diameter. The eyeballs were wanting. The tumour passed out of the skull through the frontal bone, and contained the anterior cerebral vesicles. The pineal body, which lay just behind the opening in the cranium, was very large and hydropic. Numerous and detailed figures of the condition of the brain and cranium are given in the paper. Bottez (XV.) describes a case of encephalocele protruding between the eyebrows, at the root of the nose, and of the size of an apple. The aperture of exit was situated just below the nasal spine of the frontal bone, the ethmoid being dislocated downwards. The sac contained a prolongation of the brain. The cerebral hemispheres were asymmetrical, the right being twice as large as the left, and the latter lying in the concavity of the former, which was crescentic in shape.

SPINA BIFIDA.—A lengthy monograph on this subject has been published by Taruffi (XVI.), in which the different varieties are treated historically and critically, full accounts of illustrative cases

being given. The paper closes with a discussion as to the etiology of the condition.

CYCLOPIA.—Dareste (XVII.), in a paper on the etiology of this malformation, notes that Meckel and Isidore Geoffroy St Hilaire considered that it was due to a reunion of two originally separate eyeballs, owing to atrophy of the nasal process. Huschke, on the contrary, held that it was the result of the non-separation of an originally single eye. The author's opinion is different. At the time of the formation of the defect the anterior cerebral vesicle is shaped like a short spindle, much expanded at its middle part. At its anterior extremity there is to be seen a furrow, the last remnant of the medullary groove, as yet unclosed at this point. Up to the time of the closure of this groove, the development of the vesicle takes place by a progressive invagination of the ectoderm, so that the elements which at first occupy the vicinity of the furrow are gradually pushed towards the periphery of the vesicle, whilst other portions of the ectoderm take their place. Shortly after, a constriction takes place near each of the extremities of the transverse diameter of the anterior vesicle, and thus the optic vesicles are formed. At this time the furrow has ceased to exist. The portions of ectodermic tissue destined for the formation of the optic vesicles have then passed from the edges of the furrow towards the periphery of the vesicle, a movement of passage whose extent depends upon the amount of evolution of the furrow itself. Should this become closed at the time when the elements of the two retinae are in contact, a single eye is the result. Should the union, still too premature, take place when the rudiments of the vesicles have reached the extremities of the transverse part of the cerebral vesicle, the result is the formation of two eyes, which are, however, close together and contained in the same orbit. Intermediate stages may be observed. Sicher (XVIII.) describes a case of cyclopia in a calf, in which he calls especial attention to the diminution in size of the frontal bones in his case as compared with their condition in the normal animal. Mayol (XIX.) describes the case of a foetus, otherwise well developed, in whose face were only to be observed two clefts, one situated above the other. The upper represented the palpebral opening; but there was no trace either of orbit or eyeballs, nor was there any nose. The lower cleft led into the mouth, which was normal.

DEFECTS OF THE FACE.—Taruffi (XX.) describes a case of *division of the nose*. He first gives details of three previously described cases, the best known of which is that of Selenkost (8). In his own example the baby had its nose divided longitudinally into two portions, of which the right was converted into a movable tube or proboscis 2.0 cm. in length. From the aperture at its lower end came mucus mixed with air-bubbles. There was a coloboma of the lower eyelid at the part near the attachment of the proboscis. Nüchel (XXI.) gives the following account of a case of *cleft of the cheek*. The patient, a man of low order of intelligence, aged 26, has the left side of his head and face flattened, and smaller than the right. The right nasal orifice is directed longitudinally, the left

transversely. The left orbit is narrower than the right, and the contained eye smaller. The mouth is prolonged on the left side for some distance into the cheek. From its extremity a slightly curved furrow passes upwards towards the ear, ending about 2 cm. from that organ in a slight groove. Above this there is a small cicatricial elevation, marking the place from which had been removed at an earlier date a tumour of the size of a nut, and consisting of a fibrous capsule with gelatinous contents. The above-mentioned furrow was also visible in the interior of the mouth, on opening which it was noticed that the right superior maxilla was deficiently developed. The left ear was smaller than the right, and there was no true concha, but only a transverse slit. The pinna was in other ways abnormal, as if arrested in its development. 8 mm. inferior, and somewhat posterior to the tragus, there was a small pit, 5 mm. in depth. There was complete deafness on the left side, and deficient taste sense on that side of the tongue. The sight was the same on both sides, and the ophthalmoscope revealed no differences between the two eyes. There was less motion on the left side of the soft palate than on the right. The testes were little developed. In a paper prepared by the reporter (9), an account of various cases of malformation of the face is given with a view of establishing the probability of the nervous origin of certain congenital defects. This case is of peculiar interest in this connection, and may well be contrasted with that of Otto Schmidt in particular, and with others in which very similar defects to some of those congenitally present in this individual were produced after birth by some lesion affecting the trophic nerves. Taruffi (XXII.) narrates a case of *Hypognathus Antistrophus* occurring in a calf. The additional mandible was attached to the inner aspect of the symphysis menti of the normal jaw, the teeth in the former being directed downwards. It projected forwards, i.e., out of the mouth.

HERMAPHRODITISM.—Polailon (XXIII.) describes a case of *Androgyny*, where the subject, aged 25, was possessed of female appearance and mammæ, and was indeed married as a female. In place of a vagina there was only a pit 2 cm. in depth, eventually increased by marital efforts to 7.8 cm. She had never menstruated; there was no trace of a uterus discoverable by rectal examination, but there was a small tumour present in each groin. At a later period the patient returned to hospital, and there dying, a microscopic examination showed that the tumours in question were testes.

Petit (XXIV.) describes a somewhat similar case. The subject, aged 20, was apparently a female, but was attracted towards that sex, with members of which he was easily able to effect coitus, though without ejaculation. There had never been menstruation. There was a well-developed penis without perforation; the pseudo-vaginal cavity was 7.0 cm. in depth, admitting only the minimus at its orifice. There was no trace of any inguinal tumour. Jouin (XXV.), in discussing these two cases at the Société Obstétricale et Gynécologique de Paris, surveys the whole subject of hermaphroditism, and asks whether the decision by which the individual is considered

to belong to the sex proper to the sex-glands possessed should not be revised, in view of the fact that such individuals are nearly always impotent or "neuter." Another case of Androgyny is narrated by Simmonds (XXVI.), in which the subject was a widow, aged 83. The breasts were well developed, and the aspect was feminine; there was a large imperforate penis, a pseudo-vagina 6.0 cm. in length. A testis was found in the left inguinal canal, but there was no trace of vesiculæ seminales nor of uterus. Mabaret (XXVII.) gives a case interesting because of its affecting two members of the same family, where two sisters were both affected with absence of vagina and labia majora and minora. There was a large clitoris in each case, especially in that of the elder sister, whose condition was also remarkable for the great development of the body hair.

OTHER GENITAL DEFECTS.—Voll (XXVIII.) describes a case of *uterus unicornis sinister*. The left side was normal; on the right there was neither ovary, tube, nor broad ligament, but only a band of unstriped muscular fibres passing beneath the peritoneum from the cervical part of the uterus to the wall of the pelvis. There was no right ureter, and (probably) no right kidney. In a paper by Simmonds (XXIX.) a description is given of a case of completely *double uterus and vagina* (in each of which coitus could be effected indifferently) occurring in a prostitute. Falk (XXX.) adds another to the list of cases of *super-numerary ovary*. The patient, aged 37, married three years, but nulliparous, had first menstruated at the age of 19. Abdominal section was performed for the removal of a supposed ovarian tumour. This turned out to be unconnected, so far as could be ascertained, with the uterus. It was the size of a goose-egg, and on examination proved to be a cyst with tallowy contents. On its convexity was situated a cylindrical body 6 cm. in length, the tubular lumen of which communicated with the interior of the cyst. The lumen was filled with the same tallowy substance as the cyst. Microscopic examination showed that the body in question was a Fallopian tube, dilated centrally into a cyst. The ovary was also present, but flattened over the surface of the cyst, and atrophied. As the two ordinary ovaries, with their tubes, were removed at the time of the operation, there could be no doubt that the specimen in question was an example of a third ovary and tube, the latter partly converted into a cyst. The paper contains an account of the literature of the subject.

ABDOMEN.—Dakin (XXXI.) discusses one of the cases of *ectopia viscerum*, associated with retroflexion of the whole trunk. He believes that the course of events leading up to the malformation in this case were as follows:—1. Imperfect development of the hind gut, and therefore of the allantois, resulting in (a) absence of umbilical cord and (?) of one of the vessels (umbilical arteries) normally projected on the allantois; (b) interference with outflow of urine, probably at allantoic end of ureters, producing right hydronephrosis and absence of left kidney and ureter. 2. Resulting from (a) close application of anterior surface of foetus to placenta and uterine wall, causing—3. (a) retroflexion, with its effects on the spine (meningocele and spina bifida occulta) at the point of flexion; (b) pressure-effects on the side

of the body held in contact with placenta and uterine wall; and (c) failure of abdominal wall to close.

Hamaide (XXXII.) describes a case of *ectopia vesicæ*, imperforation of the anus, absence of external genitalia and talipes varus, with dorso-lumbar spina bifida. A report upon the case by a committee of the Society deals with its causation.

Jaboulay (XXXIII.) describes a case of *interruption in the intestinal canal*, interesting on account of the probable connection of the defect with certain vascular anomalies which were also present. The child in question had lived two days. On opening the abdomen the small intestine was seen to be distended with meconium, its lower extremity floating loose at the left side. The large intestine was empty and collapsed. There was a complete absence of communication between the two. With this anomaly coincided one of the arteries, since the superior mesenteric supplied only the small intestine, and the inferior only the large, there being no anastomoses between the branches of the two arteries, the cause, according to the author, of the intestinal defect. Speaking generally, he expresses his opinion that absence of vessels, or of anastomoses between vessels, is the cause of many congenital narrowings or imperforations of passages, such as the œsophagus, rectum, and vagina, which are customarily described as arrests of development. Mitchell (XXXIV.) describes seven cases of *anomalous kidneys*. 1 and 2. Horseshoe, with bridge of renal tissue. 3. Left kidney absent; its place taken by a small grey body, with branches from the renal artery. Microscopic examination showed this body to consist of connective tissue, containing numerous inter-spaces. There was a uterus unicornis (compare this with Voll's case). 4. Right kidney absent, replaced by a small bundle with a nearly impervious ureter. Nearly complete atrophy of the kidney, says the author, occurred three times in 11,978 autopsies. The remaining cases relate to supernumerary ureters. Birmingham (XXXV.) also relates a case of kidney malformation. The left was normal; the right was joined by its upper part to the lower and inner portion of the left. The left supra-renal was in its normal position; the right lay upon the right crus of the diaphragm.

THORAX.—*Anomalies of the Breasts*.—MacGillicuddy (XXXVI.) describes several new cases of this condition, which has been dealt with during the past year in this Journal by Williams. They are: Absence of both mammæ in a hysterical patient aged 26; two axillary breasts without nipples in a female of 24; a thick milk, containing colostrum corpuscles, escaped through the pores of the skin, especially during lactation. A left axillary breast in a woman of 19 years, affording milk by two large orifices, and by two or three smaller. A female, of 26 years, had on the right side an oval breast, extending from the 7th to the 9th rib, which at the time of puberty became painful, like the others. In a man of 35 years there were two breasts—one on either side of the umbilicus, the left 4 inches, the right 3 from the middle line. A man of 35 years possessed a breast as large as that of a young woman, situated on the back of the left thigh; the neighbouring skin was traversed by large veins; there was no

areola, but a smooth nipple. A girl, aged 7 weeks, had a third breast, a little larger than either of the others, and situated between them on the middle line. Bardeleben (XXXVII.) states that of 2430 recruits examined, 76 had supernumerary nipples on the left side, 44 on the right, and 31 on both sides—making a total of 151 cases, or 6.21 per cent. All these nipples were situated lower than the normal organs. Six or eight times there were several nipples, up to as many as three or four.

Trifurcation of the Trachea.—Chiari (XXXVIII.)—The patient was a child, aged 16 days, presenting well-marked cyanosis, and with very rapid breathing. After death the heart was found to possess a very small left ventricle, the right forming almost the entire of the ventricular portion of the heart (thickness of wall, R. 8 mm.; L. 4 mm.). There was an aperture at the superior part of the septum ventriculorum, and a wide communication between the auricles. The aorta arose from the right ventricle and the pulmonary artery as a solid cord (for some distance) from the left. The right superior vena cava, formed by a vena azygos and the right brachio-cephalic vein, opened into the right auricle. The inferior vena cava and the left superior vena cava (formed by a vena azygos), the left brachio-cephalic vein, and the four pulmonary veins, united into a common stem, opened into the left auricle. Above the normal place of division of the trachea that tube gave off, on the left side, a separate bronchus, which passed to the upper lobe of a three-lobed left lung. The right stem bronchus had a double eparterial bronchus. According to the author, this case is unique, as all former cases of trifurcate trachea have been instances of premature origin of the normal eparterial bronchus, to the right side in the ordinary condition, and to the left in that of situs transversus. In this case there was also absence of the spleen, and the lig. hepato-duodenale lay to the left of the gall-bladder, and anterior to the pyloric end of the stomach. It contained in its free border the common bile-duct, the hepatic artery, and the portal vein, and formed the anterior wall of a blind peritoneal pouch, the posterior wall of which was formed by the lesser omentum.

Taruffi (XXXIX.) describes a curious condition of the *heart* found in the body of a boy aged 12, who had been cyanotic during life. There were two apertures through the fossa ovalis. The right ventricle was much larger than the left, and its walls were greatly thinned. The orifice of the pulmonary artery was somewhat enlarged. The auriculo-ventricular orifice was much enlarged, and from its anterior two-thirds there sprang a thin transparent membrane like the cusp of a valve, which descended to the apex of the heart, where it became continuous with the endocardium. At various parts of its surface were attached chordæ tendineæ and muscoli papillares. It was connected with the endocardium along the right border of the heart. On the left side was an oval deficiency bounded on the left by the septum ventriculorum, and on the right by the free border of the membrane. There was no evidence of foetal endocarditis. The author considers that the condition is explained by a persistence of the foetal structures from which the chordæ are formed.

Calori (XL) found a case of *inversion of the thoracic duct* in the body of a man aged 70. The right subclavian artery was the last vessel given off from the aortic arch, and passed behind the trachea. The larger thoracic duct passed into the right subclavian vein by two tubes, of which the larger was external to the jugular vein, and the smaller posterior to the same. There was a small duct on the left side in the usual position.

LIMBS.—*Absence of a part of both clavicles* is described by Van d. Bussche (XLI.) as occurring in a man aged 30. The bone on either side was 3.5 cm. in length and 0.75 in breadth, and there was an interval from the outer end of one clavicle to the outer end of the other of 12.0 cm., that between the two acromia being 29.0 cm. No ligamentous continuation of either clavicle could be made out (the subject was living). The condition of the muscles as ascertained by manual and electrical examination was as follows:—The clavicular part of sterno-cleido-mastoid was small, and that of the trapezius arose from the coracoid process, as did the corresponding portion of the deltoid. There was no subclavius. The author mentions several cases of the same malformation, to which may be added the interesting case (10) where imperfection of one or other end of the clavicle ran through three generations of a family. In Gegenbaur's case (11) the affection was also hereditary.

Variot (XLII.) gives an instance of *hemimelia* occurring in a boy aged 3 years. The left arm was alone malformed, appearing as if amputated at the superior third. The ends of the radius and ulna could be felt. Five skin tubercles representing the digits were present on the end of the stump. On microscopic examination these were found to contain no bone or cartilage, but to consist internally solely of fibrous tissue. The muscles, nerves, and arteries of the arm were normal, and the brachial divided into minute radial and ulnar arteries. The cervical portion of the spinal cord was microscopically examined, when it was found that the anterior cornua of the affected side were one-fourth smaller than those of the normal. With this observation, so far as it concerns the nervous system, may be compared the note by Gowers (12) on the brain, in a case of congenital absence of one hand, and a case by Spillmann (13), where, in combination with an ill-developed hand on one side, there was a decrease in size of the anterior cornu of the spinal cord in the cervical region. In other respects, a very similar case is described by Sturge (14), where there were the curious miniature skin digits to which the author alludes. I have recently received from my colleague, Mr Jordan Lloyd, a specimen showing this condition to perfection—a condition which is dealt with in a careful and suggestive manner in Sturge's paper.

Poelchau (XLIII.) is the author of a paper which gives an account of a case of *perodactyly* affecting one foot (the right), which possessed only four toes, the hallux and three others. The muscles of the hallux presented nothing worthy of notice. There was a muscle on the outer side of the fourth metatarsal resembling an abductor minimi digiti, and there were three dorsal and two palmar interossei. The

normal number of tarsal bones was present. The fourth metatarsal had not the characteristic spur of the fifth. The author thinks that this toe must be looked upon as a representative of both the fourth and the fifth.

Mies (XLIV.) describes a very similar case affecting the hand. The subject was a man aged 22. The right hand was shorter than the left, and the metacarpal bone and three phalanges of the fifth digit were quite absent. The right forearm was slightly smaller than the left. The author states that he has been only able to find four similar cases in literature; but to these may now be added one by Polaillon (XLV.), where there were exactly similar conditions present, but on the left side. There was no trace of heredity in either case.

Jolly (XLVI.) gives a full account of a very remarkable case of *polydactyly* with malformation of the arm. The subject is a male aged 25, and no abnormalities of the hand have been known in his family. The whole of the left arm is smaller than its fellow, and it is also shorter. In the place of the biceps there is a strong bony ridge. The head of what should be the radius is absent, and the lower end of the same bone is not expanded in the usual manner, but is small and rounded like the end of the ulna. There are six fingers, which appear to be arranged in two sets, three and three, with a deep cleft between the two groups. Each group consists of a minimus and two other digits, thus on the outer side the pollex is replaced by a minimus, or at least by a finger resembling that digit. It thus appears as if the hand was made up of the minimus, annularis and medius digits of a right and a left hand. The medius of the radial group has two metacarpal bones, with both of which the first phalanx articulates. An electrical examination of the musculature shows that there is abduction of both sides of the hand, but no opposition; there is a muscle on each side which appears to be a *palmaris brevis*, and there is no pronator radii teres. Thus the appearance of two fused hands, and even arms, is rendered more complete. This singular case may be compared with the example of double-hand described by Jardine Murray (15). A case of polydactyly in a man aged 60, where there were on the right hand six digits and on the left seven, on the right foot seven toes and on the left six, is worthy of mention, because of the co-existence of simple harelip, and of the complete absence of heredity upwards or downwards.

I may perhaps be allowed to refer to a paper published in this Journal on the presence of an *additional phalanx in the human pollex* (XLVIII.), in order to give the following references to similar cases of this rare condition, which I owe to my friend Mr W. Bateson:— (1) Guermonprez, F., *Rev. des Mal. de l'Enfance*, 1886, p. 122; (2) Rijkebusch. *Bijdr. t. d. Kentniss. d. Polydactylie*, Inaug. Diss., Utrecht, 1887; (3) Kuhnt, *Virch. Arch.*, t. lvi. s. 268; (4) Stark's *Archiv f. Geburtshilfe*, 1801, t. xv. s. 641. I may also say that I have seen, since the paper was published, a second case of the same abnormality, again through the kindness of Mr Jordan Lloyd, where the three-phalanged pollex was the radial of the two pollices.

MUSCULUS STERNALIS.—This slight abnormality is perhaps hardly in place in an article on teratology, but as I have a series of references to papers which have appeared during this year, I may be allowed briefly to detail them for the use of those working at the morphology of a muscle which has attracted so much attention.

Le Double (XLIX.) in his paper gives details of thirty-three sternalis, of which nineteen were in males and fourteen in females—seventeen were double, sixteen single; and of the double, twelve were independent of one another, the remaining five being more or less connected. These were obtained from 722 subjects. Taking the returns of other writers, the author constructs the following table :—

	Sternales.	Subjects.
Wood.....	7	175
Turner.....	21	630
Wenzel Gruber.....	5	95
Macalister.....	21	350
Le Double.....	33	722
	—	—
	87	1972, or about 5 per cent.

The nerve of supply to the muscles in these instances is not mentioned, and the view taken of their morphology is that they are derived from the panniculus.

Schwalbe and Pfitzner (L.), in a paper on Anatomical Statistics, mention that they have observed the sternalis four times in 238 bodies.

Fick (LI.) has described three new examples, in each of which he states that the nerve-supply was derived from the intercostals.

Smith (LII.) also describes a case occurring on both sides of the body, in which, according to his statement, the nerve-supply was not derived from the anterior thoracics.

Nicolas (LIII.) saw twin foetuses both possessed of sternalis. The mother being still in hospital was examined by electricity, and found to possess the same muscle. I think this is the first demonstration of the heredity of this muscular abnormality.

The reporter thanks those authors who have sent him copies of their papers, and will feel much obliged to authors who may furnish him with reprints of teratological papers, for use in the preparation of future reports.

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ABNORMAL POSITION OF MECKEL'S DIVERTICULUM.

By G. AYLWIN CLARKSON and FRED. S. COLLARD, *Students of St George's Hospital.*

IN connection with the recent report of the Collective Investigation Committee of the Anatomical Society, this note of a diverticulum connected with the commencement of the jejunum is, from its unusual position, perhaps worth recording. A diverticulum was found connected with the small intestine lying horizontally in the umbilical region above and to the right side of the umbilicus. This diverticulum, which resembled Meckel's in conformation, was found to be connected with the jejunum, and was situated 2 feet from the pylorus. It measured $1\frac{1}{2}$ inches in length, and its lumen was equal to that of the gut. Its wall was of the same thickness as that of the jejunum, and was lined with a prolongation of the intestinal mucous membrane. It lay with its free extremity away from the mesentery, and had a process from the adjacent mesentery of the jejunum passing to its posterior surface, and reaching to within $\frac{1}{2}$ inch of its free extremity. No fibrous cord was attached to the latter. It was distended with air, and there were no adhesions between it and any of the surrounding intestines.

The subject was a man aged 75, body well nourished, and above the average height.

There is a somewhat similar specimen showing this rare condition in the museum of this hospital,¹ in which the pouch opens from the jejunum in its 3rd or 4th inch. It arises from the attached side of the gut, and lies between the layers of the mesentery, its wall being much thinner than that of the intestine. The subject was a man also, aged 61.

In the cases reported by the Collective Investigation Committee, and in thirteen cases recorded in the post-mortem books of St Bartholomew's Hospital,² 1867-1883, the highest point at which this diverticulum occurred was 120 inches from cæcum, in the majority of the cases being found within the last 36 inches of the small intestine.

¹ Series ix. 71B.

² *Path. Soc. Trans.*, vol. xxxv. p. 208.

Journal of Anatomy and Physiology.

ON THE RELATIONS BETWEEN THE WEIGHT OF THE BRAIN AND ITS PARTS, AND THE STATURE AND MASS OF THE BODY, IN MAN. By the late JOHN MARSHALL, LL.D., F.R.S., F.R.C.S., *Emeritus Professor of Surgery in University College, London, President of the Medical Council of Great Britain and Ireland.*

I. THE RELATIONS BETWEEN THE WEIGHT OF THE BRAIN AND ITS PARTS, AND THE STATURE, IN MAN.

THE first part of this paper is devoted to a confirmation and extension of the conclusions recorded in a short communication already published in the *Proc. Roy. Soc.*, No. 163, 1875. The materials on which it is based, and the tables which it contains, are derived and constructed in part from the facts recorded by the late Dr Robert Boyd in the *Philosophical Transactions* for 1861, in part from his original MSS., and partly from fuller tables prepared by him to forward my purposes in regard to the present inquiry.

Whilst recently engaged in examining the brain of the late Mr George Grote, the historian of Greece, I endeavoured to obtain some definite information concerning the influence of variations in the stature on the weight of the brain and its several parts in Man. As is well known, the ratios of the weights of the encephalon or entire brain, of the cerebrum, and of the cerebellum, to the *weight* of the body, have been investigated by many observers, both past and present, including Sims, Clendinning, Tiedemann, Reid, Peacock, Boyd, Huschke, Wagner, Weisbach, and others of less note; but the great variation met with in the weight of the body, dependent on its different condition as to obesity or emaciation, at the moment of death, renders the numerical results thus obtained of little value as indications of the real relations which must exist between the development of the encephalon and its parts, and that of the body in fully grown and healthy persons of either sex. Tiedemann (*Das Hirn des Negers*, Heidelberg, 1837; *Phil. Trans.*, 1836, vol. cxxvi.), for example, than whom no one has examined

this question more thoroughly, found the proportionate weight of the brain to that of the body, in the adult, to range from 1 to 100 in very fat persons, and 1 to 27 in very lean ones; and it was only by the exclusion of extreme cases, and the selection of subjects of medium stoutness, that a mean ratio of about 1 to 40 (more nearly according to others, 1 to 36·5) was arrived at by him, for the average healthy adult, irrespective of sex and of exact age. Such and all similar results are entirely unsuited to form the groundwork for estimating the normal ratio of the weight of the encephalon to the actual mass of the body in individual cases; much less can the same method be trusted, as employed by Huschke and others, for the further attempt to determine the relative weights of the several parts of the encephalon, as compared with the body-mass.

The influence of *Stature* on the brain-weight in Man was first shown numerically by Parchappe (*Recherches sur l'encéphale*, &c., Paris, 1836), but his results are founded on a very small number of observations. The statements of other writers are of a general kind only. It is, of course, well established that the brain, taken as a whole, is absolutely heavier in men than in women, chiefly, as is admitted, on account of the greater stature and bulk of the stronger sex; and, herein, a certain influence of stature has necessarily been acknowledged. It has been further shown that, considering the two sexes apart, the brain is, as a rule, or on an average, absolutely heavier in tall than in short individuals; but the facts hitherto recorded, bearing upon this point, are very few. Again, the existence of a direct relation between the size of the brain, or rather between that of the cranium and the stature, has often been invoked in the explanation of the smaller cranial capacity of certain of the shorter and smaller races of mankind, such as, for example, the Hindoos, as compared with other Aryan races. Parchappe found that the variation in the absolute weight of the brain accompanying a difference in stature amounting to $3\frac{1}{2}$ inches was about 5 per cent. of its total weight, and that it was greater amongst men than women. But he based these two conclusions upon a comparison of only 9 tall persons, 5 males and 4 females, with 10 short ones, 5 males and 5 females. The mean height of the tall persons was 65·75 inches, that of the short persons, 62·25 inches; the mean weight of the brain in the former was 45·25 oz., and in the latter, 43·75 oz. (*op. cit.*, pp. 101–76).

As to the *relative* or *proportionate* amount of brain in comparison with the stature, in persons of different heights, neither Parchappe nor any other observer has endeavoured to estimate this point numerically, unless with reference to the difference of stature in the two sexes. Dr Thurnam (*On the Weight of the Brain*, &c., London, 1866, p. 15), indeed, states that Parchappe “inferred, that the weight of the brain in both sexes is relatively greater in tall persons than in short ones, &c. ;” but this is not a correct interpretation of Parchappe’s words, which are to the effect that in both sexes, the brain is sensibly heavier according to the stature, or “on account of the stature” (“en raison de la taille ;” *op. cit.*, p. 76). In

fact, his meaning is that the brain is merely *absolutely* greater, not *relatively* greater, in tall than in short persons. Its relative proportions to the stature, in persons of different heights, are, in truth, not discussed by Parchappe at all, except in relation to the sexual differences. At the same time, if he had done this, his data, though so limited in number, would have shown him that the brain is relatively to the stature smaller in tall than in short persons of either sex, which, indeed, will be presently proved to be the case by reference to sufficiently ample data. It may here be noticed that M. Broca (*Mémoires d'Anthropologie*, t. i. p. 165, 1871), in discussing M. Parchappe's results, makes it appear that the percentage of cerebral difference between the tall and short males is identical with the percentage of their differences in height, stating that, both as regards the brain-weight and the stature, the increment in the tall males is exactly 6 per cent. over the quantities in the short ones. But the exact figures are 6.02 per cent. for the increase in the brain-weight, and 6.75 per cent. for that of the stature; so that, as just said, Parchappe's observations, though insufficient in number, really show that the brain is relatively to the stature somewhat smaller in tall persons. In the females, the respective figures are 2.02 per cent., and 5.92 per cent., thus establishing the same conclusion, but, as will hereafter be seen, in an exaggerated manner, owing doubtless to the paucity of the observations.

Weisbach, "Die Gewichtsverhältnisse der Gehirne," &c., *Archiv für Anthropologie*, Braunschweig, 1866-7, pp. 316-7. Weisbach has examined the influence of stature on the weight of the brain and its parts in a much larger number of cases than Parchappe, viz., in 429 subjects, the greater proportion of whom were males, being soldiers of various nationalities belonging to the Austrian Empire. But he has merely grouped his observations into three categories as to stature, without any record of individual measurements, and his conclusions as to the relation between the brain-weight and the height of the body are expressed in words and not numerically. With his most general conclusion, my own results are at variance; for, dividing his cases into those of large, middle-sized, and small persons—the latter being at least 5 feet (Vienna measure) high—he finds that the encephalon is *absolutely* heaviest in the middle-sized, and not in the largest-sized individuals, as is usually believed, and as I shall presently show to be the fact. As to the cerebrum and cerebellum separately considered, he does not compare them directly with the stature, so as to determine their proportionate weights in reference to the height, at different statures; but he compares each organ with the entire encephalon, in his three groups, and finds that, thus estimated, as the stature increases, the proportion of cerebrum to the whole brain diminishes, whilst that of the cerebellum increases—a conclusion which I can so far, but in a different manner, confirm.

In discussing the influence of Stature, as exhibited in a comparison of men with women, and as affecting the respective brain:

weights of the male and female, Parchappe (*op. cit.*, p. 70) instituted an ingenious mode of comparison between the sexes, for which Thurnam (*op. cit.*, pp. 15, 16) omits to give him credit, although he proceeds to employ it in calculations founded on the more extensive observations recorded in Dr Boyd's tables (*Phil. Trans.*, 1861). Parchappe pointed out that, whereas the ratio of stature between a given number of males and females was 1000 to 927, the ratio of their respective brain-weights was 1000 to 903. Hence, he concludes, in accordance with the statement of Aristotle, and in opposition to that of Meckel and others, that the brain in the female is smaller in proportion to her height than it is in the male in proportion to his. He moreover shows that, on adopting the estimated ratio of the weight of the body in the male to that of the female, given by Quetelet, viz., 1000 to 867, the curious result is arrived at, that, in reference to the weight of the body, as indeed Tiedemann found (*Phil. Trans.*, 1836, vol. cxxvi. p. 306), the female brain is heavier than the male brain. From the far more numerous data employed by Thurnam, the several ratios between the male and female proved to be as follows:—Of stature, 1000 to 932 ; of brain-weight, 1000 to 903 ; of body-weight, 1000 to 872—results which nearly concur with and confirm those of Parchappe.

It is obvious, however, that many of the above mentioned conclusions, whether expressed generally or numerically, exhibit, after all, the combined effects of at least two modifying conditions, viz., that of sex and that of stature, acting, it may be, in one or in opposite ways ; so that, in order to eliminate sexual and other influences, and determine that of stature by itself, further inquiries are needed, in regard to the two sexes separately. Moreover, besides the effects of stature on the relative size of the entire brain, there remains to be considered its influence on the cerebrum and cerebellum respectively.

In investigating these points, I at first intended to have employed as one term in the requisite series of comparisons the estimated *normal weight of the body at its different heights* in each sex separately, and then to have taken the ratio of that normal weight to the mean ascertained weights of the encephalon and its several parts, at corresponding heights in the two sexes. In the well-known tables of M. Quetelet, and the less known tables of Dr Beddoe, materials for such determinations are to be met with. But, on trial, I found that a less circuitous and therefore, in the first instance, a preferable method—one, indeed, which was closer to the facts—was to take the *ascertained heights*, in the different cases, turn them into inches, and find how

much, expressed in *decimal parts of an ounce*, of *encephalon*, of *cerebrum*, of *cerebellum*, and of *pons with the medulla oblongata*, was associated with every *inch of height*. Being well aware of the fact that the *length of the trunk*, which is dependent chiefly on that of the vertebral column, is more uniform throughout a number of individuals than the *total height*, as measured from head to foot in the standing posture, which is largely influenced by the variable development of the lower limbs, I should have preferred to have employed the first-named standard of measurement. But, so far as I am aware, no observations of this kind have been made in conjunction with determinations of the weights of the encephalon and its parts in corresponding individuals, so that I was constrained to employ the total height.

In one of Dr Boyd's published tables (*Phil. Trans.*, 1861, vol. i. pp. 249-53) there is a record of the *average height* of 652 males of various ages, from twenty to eighty years and upwards, together with the *average weights* of the encephalon, the cerebrum, the cerebellum, and the pons with the medulla oblongata, at the corresponding periods of life. From this record I have constructed the following Table I., to which I have added the ratios of weight to height, calculated in the manner above mentioned, and also the ratio of the cerebrum to the cerebellum. The results are so regular as to create some confidence in this method of determining the relations between the weight of the brain and its several parts, and the stature of the body.

TABLE I.

Table showing in 652 adult *males*, at different decennial periods of life, from twenty years to eighty years and upwards, the *average weight and height* of the body; the *average weights* of the encephalon and its three chief subdivisions; the ratios of each of these to the stature, calculated in decimal parts of an ounce to every inch of height; and, lastly, the ratios of the cerebrum to the cerebellum, the latter being valued as 1. (The facts were collected by Dr Boyd in the St Marylebone Infirmary.)

Males.

No. of Cases.	Age.	Average Weight in lbs.	Average Height in inches.	Average Weights in oz. Av.				Ratio of Weights in parts of an oz. to an inch of Height.				Ratio of Cerebrum to Cerebellum.
				En- cephalon.	Cere- brum.	Cere- bellum.	Pons and Medulla.	En- cephalon.	Cere- brum.	Cere- bellum.	Pons and Medulla.	
55	20-30	92.14	66.75	47.9	41.98	5.19	.98	.718	.629	.078	.014	8.09-1
103	30-40	93.35	66.5	48.2	42.07	5.15	.98	.725	.632	.077	.015	8.17
185	40-50	102	66.8	47.75	41.48	5.22	1.06	.715	.621	.078	.016	8
110	50-60	102.5	66	47.44	41	5.13	.98	.714	.621	.078	.015	8
123	60-70	103.13	65.7	46.16	40.21	4.98	.97	.701	.612	.075	.014	8.07
102	70-80	106.13	65.7	45.5	39.6	4.96	.94	.69	.602	.074	.014	8.1
24	80-90	99	66.7	45.34	39.62	4.79	.89	.68	.6	.073	.013	8.27
652	20-90	99.75	66.3	46.88	40.85	5.06	.97	.708	.619	.075	.014	8.07

The numbers of the cases examined, given in the first column of this table, show that these are sufficient to yield fair averages of heights and weights for comparison. Passing over the second column, which indicates the age of each group of cases, to the third, which contains the weights of the body, it is seen that these latter, even though reduced within certain bounds by the system of averages, exhibit no regular proportion to the heights of the body, or to the weights of the encephalon and of its parts; on the contrary, they remain far too irregular to be safely used as an element in the comparisons needed for the present inquiry.

The *average height*, in each group of cases, is, however, as shown in the fourth column, a far more uniform and regular factor, thus offering itself to notice as a safer basis of comparison.

The next four columns give the average weights of the encephalon, the cerebrum, the cerebellum, and the pons with the medulla oblongata, in the several decades of life, from twenty to eighty years and upwards. These figures show that the absolute weights of all these parts culminate, as a rule, in the decennial period extending from thirty to forty years, after which they decrease, at first slowly, and then more rapidly with advancing age. But besides these now acknowledged facts, the figures

indicate that these several parts diminish as life advances in different proportions. Thus, the actual decrease in the cerebrum, the cerebellum, and the pons with the medulla oblongata, between the ages of forty and eighty, is seen to be 2·47 oz., ·19 oz., and ·04 oz. respectively, so that at the age of eighty they have lost $\frac{1}{7}$ th, $\frac{1}{27}$ th, and $\frac{1}{24}$ th of their respective weights at the age of forty. The cerebrum, accordingly, appears to suffer more loss from the effects of age than the cerebellum, not only undergoing a greater absolute diminution, but a greater amount of waste, proportionally to its own size, an important result, quite consistent with the presumed greater use of the former organ in relation to the mental processes.

The succeeding four columns contain the *ratios* between the *weights* of the encephalon and its three subdivisions, on the one hand, and the *stature* of the body on the other, expressed in decimal parts of an oz. av. to every inch of height, as this is recorded in the fourth column. These *stature-ratios* of the several organs, as they might be termed, display a very interesting progressive regularity at the different periods of adult life; but they also confirm, or show in another form, the declining weight of the encephalon and its parts as life advances, not only when considered in an absolute manner, but also, as just pointed out, when regarded in relation to the stature.

In the last column but one are set down the *ratios between the weights of the cerebrum and cerebellum*, at the several periods of life. These *cerebro-cerebellar* ratios display considerable irregularity, dependent on the condition, not sufficiently recognised, that they result from the comparison of *two* variable factors. The importance of this particular ratio, standing by itself has, indeed, been over-estimated; for it does not indicate whether a large or small proportion of cerebrum to cerebellum, in any given instance, is due to an individual peculiarity in the weight of one or other organ, or in that of both in opposite directions. To this point I shall possibly recur. Though not relevant to the present inquiry, a series of total averages of weights and ratios is given at the bottom of the several columns, not only for the sake of completeness, but on account of the interest which these possess, as will be seen when they are compared with the corresponding totals in the next table.

TABLE II.

Table showing the same facts as in Table I., but in relation to 715 adult *Females*. (Observed by Dr Boyd in the St Marylebone Infirmary; *op. cit.*, pp. 249–53.)

Females.

No. of Cases.	Ages.	Average Weight in lbs.	Average Height in inches.	Average Weights in oz. Av.				Ratio of Weights in parts of an oz. to an inch of Height.				Ratio of Cerebrum to Cerebellum.
				En- cephalon.	Cere- brum.	Cere- bellum.	Pons and Medulla.	En- cephalon.	Cere- brum.	Cere- bellum.	Pons and Medulla.	
70	20–30	86·13	62	43·7	38	4·82	·88	·705	·613	·077	·014	7·9–1
85	30–40	87	62	43·09	37·92	4·74	·91	·695	·611	·076	·015	8
97	40–50	84	62	42·81	37·12	4·69	·89	·690	·600	·075	·014	7·9
100	50–60	86	62	43·12	37·38	4·62	·86	·695	·603	·074	·014	8
142	60–70	86·14	61·5	42·69	37·13	4·68	·83	·693	·603	·076	·0135	7·9
146	70–80	80·4	61	41·27	35·58	4·47	·88	·674	·583	·073	·014	7·8
75	80–	79·5	60	39·77	34·47	4·47	·82	·663	·574	·074	·013	7·6
715	20–80	84·19	61·5	42·35	36·82	4·66	·87	·688	·599	·075	·014	7·85

This table illustrates the same general relations of the brain-weights to the age and the stature in females, as those already given in regard to males. The weights of the body are here also, as in the previous table, less regular than the heights. On consulting the totals at the bottom of the table, it will be seen that, on an average, the female encephalon is about $4\frac{1}{2}$ oz. lighter than the male encephalon—the difference in the cerebrum of the two sexes accounting for 4 ozs. of that quantity, the rest being referable almost entirely to a difference of $\frac{4}{10}$ ths of an oz. in the cerebellum. It will furthermore be observed, however, that these sexual differences are not to be wholly explained by the difference of stature in the two sexes; for the encephalon is shown to be not only absolutely smaller in the female, but to be so even *relatively to the height of the body*. Thus, the average proportion of entire brain in the female series is only ·688 oz. to every inch of height, instead of ·708 oz., as in the male series. It is, moreover, of importance to note that, as

thus tested, the relative preponderance of the encephalon to the body in the male, or its deficiency in the female, appears to exist entirely in the cerebrum, the average stature-ratio of that organ being $\cdot 619$ oz. in the male, and $\cdot 599$ oz. in the female series, whilst the average stature-ratios of the cerebellum, and of the pons with the medulla oblongata, are similar in the two sexes. The definite character of these results is of undoubted interest, and their confirmation would alone serve to prove the value of the mode of comparison, here adopted, between the weights of the encephalic organs and the stature in the two sexes.

On looking at the figures in the last column of this table, it will be seen that the ratio of the cerebrum to the cerebellum in the female series, exhibits as much irregularity at the different periods of life, as it did in the male series shown in Table I.

Nevertheless, on comparing the corresponding figures in the two tables, they indicate that, whilst with advancing age, the proportion of cerebrum to cerebellum increases in men, it, on the contrary, diminishes in women; moreover, the mean ratios, given at the bottom of the two columns, show that the proportion of cerebrum to cerebellum, taken at all ages, from twenty upwards, is greater in the male than in the female sex, being $8\cdot 07$ to 1 in the former, and $7\cdot 85$ to 1 in the latter. But, as already alluded to, these differences in the cerebro-cerebellar ratios in each sex at different ages, and in the two sexes at all ages, are so far illusory, as they may be due either to variations in one or other organ, or in both organs.

Now, a consideration of the stature-ratios of these organs under the different conditions of sex and age, as above recorded, at once throws light upon the questions at issue.

In the first place, the difference between the two sexes generally, as regards their cerebro-cerebellar ratios, appears to be due to a decided and real preponderance of cerebrum in the male, as compared with the female, in the proportion of about 62 to 60 (*i.e.*, as measured against the stature, of $\cdot 619$ to $\cdot 599$), and not to any marked difference either way in the cerebellum, which, as also measured against the stature, is of equal size ($\cdot 075$) in the two sexes. In the second place, as regards the opposite effects of age on the cerebro-cerebellar ratios in the

two sexes, it is shown by reference to the series of stature-ratios in the male and female series, at different periods of life, that the proportion of cerebrum to cerebellum is modified by a two-fold and contrary condition in each sex; for whilst, with age, the cerebrum diminishes less in reference to the stature in men than in women, viz., in about the proportion of 3 against 4 (*i.e.*, $\cdot629 - \cdot600 = \cdot029$ against $\cdot613 - \cdot574 = \cdot039$), the cerebellum diminishes more in men than in women, viz., in the proportion of 5 to 3 (*i.e.*, $\cdot078 - \cdot073 = \cdot005$ against $\cdot077 - \cdot074 = \cdot003$). This curious result coincides entirely with a conclusion arrived at by Weisbach on other grounds (*op. cit.*, p. 317), viz., on a comparison of the weights of the cerebrum and of the cerebellum with that of the entire encephalon, in a certain number of men and women at various ages; by which means he shows that, with age, in men, the proportion of cerebrum to the entire encephalon becomes greater, whilst that of the cerebellum becomes less; whereas, in women, with age, the proportion of cerebrum becomes less, and of cerebellum greater, in comparison with the entire encephalon.

It seems possible, moreover, that the unobserved influence of stature might serve to account for the conclusions arrived at by both Huschke (*Schaedel, Hirn und Seele des Menschen*, &c., Jena, 1854), and R. Wagner (*Vorstudien, &c., Abhandlungen der Koeniglichen Gesellschaft, &c., Goettingen*, 1861, p. 93), to the effect that if the *weight of the body* be taken as a standard of comparison, the cerebrum appears to be larger in women, and the rest of the encephalon larger in men, conclusions not easily admissible, and directly opposed to those of Weisbach and myself just stated. It is likewise not impossible that a reference to the effects of stature might explain, at least in part, a very remarkable and apparently incongruous contrast observed by Weisbach, as existing between the sexes, in the South German and Slavonic brains which he examined, viz., that in the German women the proportion of cerebrum to the entire encephalon was larger, whereas that of the rest of the brain was smaller, than the corresponding proportions of those parts in the German men; whilst in the Slavonic brains, the female cerebrum, as compared with the entire brain, was relatively smaller, and the rest of the brain (including the cerebellum,

pons, and medulla) was larger than in the male, in which sex the cerebrum was relatively to the entire brain larger, and the cerebellum smaller. In the Slavonic women, the cerebrum was relatively smaller, and the cerebellum, pons, &c, were relatively larger than in the German women (*op. cit.*, p. 317).

Having thus examined the more general effects of stature on the encephalon and its parts, as detected by a comparison of *average* brain-weights with *average* heights, in the two sexes, the next step to be taken is to endeavour to determine its influence, if any, on the absolute and relative weights of the encephalon and its parts in *individuals*, or *groups of individuals*, of different known heights, in the two sexes separately. Now, in Dr Boyd's published tables, there are two series of maximum and minimum heights, and maximum and minimum weights of organs, in both sexes; but these merely constitute a register of the greatest and the least heights and weights met with in his entire research, and have no *individual* relation to one another. I accordingly appealed to Dr Boyd for permission to examine such of his original documents as might furnish the required data. From two sets of manuscript tables, which he at once placed at my disposal, containing the heights and the weights of the organs required, in 320 adult males and 325 adult females, all belonging to the insane class however, I constructed the two following tables.

TABLE III.

Table showing the average weights of the encephalon and its parts, and the ratios between those weights and the stature, together with the ratios of the cerebrum to the cerebellum, in 320 adult *male* lunatics, ranging between twenty and eighty years and upwards, and placed in five groups according to their heights. (From cases observed by Dr Boyd in the Somerset County Lunatic Asylum.)

[TABLE III.]

Males.

No. of Cases.	Heights in Groups of 8 inches.	Average Weights in oz.				Ratios of Weight in parts of an oz. to each inch of Height.				Ratios of Cerebrum to Cerebel- lum.
		Enceph- alon.	Cere- brum.	Cerebel- lum.	Pons and Medulla.	Enceph- alon.	Cere- brum.	Cerebel- lum.	Pons and Medulla.	
67	70-72	48.18	41.6	5.47	1.11	.678	.586	.077	.015	7.6 to 1
122	67-69	47.83	41.5	5.24	1.09	.703	.610	.077	.016	7.9 „ 1
103	64-66	46.92	40.8	5.04	1.08	.722	.627	.0775	.016	8 „ 1
21	61-63	45.59	39.8	4.8	.99	.735	.643	.079	.016	8.1 „ 1
8	58-60	46.02	40.35	4.7	.97	.780	.682	.08	.0164	8.5 „ 1
320	70-60	46.91	40.81	5.05	1.05	.725	.630	.078	.015	8.02 „ 1

Neglecting the lowest group of cases, viz., that between 58 and 60 inches in height, as including so small a number of facts, it is shown that between the heights of 61 and 72 inches the absolute weight of the encephalon increases with the stature by 2.59 oz., i.e., by $\frac{1}{7}$ th of its own weight at the lower stature. Of this increase, the cerebrum takes 1.8 oz., the cerebellum .67 oz., and the pons with the medulla .12 oz., i.e., quantities which are equal to $\frac{1}{22}$ nd, $\frac{1}{7}$ th, and $\frac{1}{8}$ th of their respective weights at the lower stature. Considering the size of the two organs, the cerebellum in the *insane*, increases, therefore, in absolute weight more than the cerebrum, as the height of the body is increased.

Studying next, however, the columns containing the stature-ratios, or ratios of weights in ozs. to inches of height, it is plain that, in these cases also, the encephalon and its parts do not keep pace in growth, with the growth of the body; for, in each instance, the proportion to every inch of height becomes less as the stature itself increases. In the case of the encephalon the proportion varies from .735 to .678; in that of the cerebrum from .643 to .586; and in that of the cerebellum from .079 to .077 decimal parts of an oz. to every inch of height. Moreover, it is evident that this diminution of the ratio of brain substance to the body, which appears to occur in the taller insane individuals, is greater in the case of the cerebrum than in that of the cerebellum, amounting in the former to $\frac{1}{7}$ th of the cerebral stature-ratio at the lower stature, and in the latter to only

about $\frac{1}{40}$ th of the corresponding cerebellar stature-ratio. It is therefore apparent that, *relatively to the body*, the cerebellum changes less, or, in other words, follows the stature more closely than the cerebrum, which condition, however, we shall find is peculiar to the insane, and is connected with the waste of the cerebrum, and the preponderance of the cerebellum due to or accompanying the insanity. The unequal influence of stature on these two organs is also well illustrated by the progressive differences in the ratios of the cerebrum to the cerebellum, at different heights of the body; for, whereas, as shown in the final column, the ratio, in insane males between 58 and 60 inches in height, is 8·5 to 1, it changes step by step, until it becomes only 7·6 to 1, in persons measuring from 70 to 72 inches. In this case, the test of stature shows most conclusively that, in the insane, both organs diminish relatively to the body, as the stature increases, but the cerebrum more than the cerebellum.

It may here further be observed that, since, as already shown in Tables I. and II., the cerebrum diminishes more according to the age, and, as now indicated, increases less according to the stature, than the cerebellum, so the combined effect of both these influences in diminishing its stature-ratio is greater in tall than in short persons; and, conversely, as the cerebellum diminishes less by age, and increases more with the stature, so the joint effect of both these influences upon its stature-ratio will be more marked in short than in tall persons.

From all that has preceded, the cerebrum presents itself to us as a more independent organ than the cerebellum, in reference to the body generally; for it is less uniformly developed with, and in proportion to the stature, and it undergoes relatively greater waste from age; whilst, on the contrary, the cerebellum, in both respects, shares the fortunes of the body more closely.

So far as can be determined, the pons and medulla oblongata seem, as might be anticipated, to follow the condition of the cerebellum rather than that of the cerebrum.

TABLE IV.

Table showing the same particulars as Table III., but relating to 325 adult *female* lunatics, between twenty and eighty years

of age and upwards. (From cases observed by Dr Boyd in the Somerset County Lunatic Asylum.)

Females.

No. of Cases.	Heights in Groups of 3 inches.	Average Weights in oz. Av.				Ratios of Weights in parts of an oz. to an inch of Height.				Ratios of Cerebrum to Cerebellum.
		Encephalon.	Cerebrum.	Cerebellum.	Pons and Medulla.	Encephalon.	Cerebrum.	Cerebellum.	Pons and Medulla.	
8	67-68	42.53	36.62	4.9	1.01	.628	.542	.072	.014	7.5 to 1
118	64-66	41.88	36.27	4.63	.98	.644	.558	.071	.015	7.8 „ 1
185	61-63	42.92	37.11	4.82	.99	.691	.598	.077	.016	7.7 „ 1
65	58-60	41.36	35.97	4.47	.92	.700	.610	.075	.015	8.03 „ 1
6	54-57	39.03	34	4.16	.87	.697	.607	.074	.015	8.17 „ 1
325	54-68	41.64	36.0	4.59	.95	.672	.583	.074	.015	7.84 „ 1

This table shows that in insane women, as in insane men, the encephalon increases absolutely in weight with an increase of stature ; but the quantities indicated are not quite so regular as in the corresponding columns in Table III., relating to men.

It is also obvious that, taking a range of stature in both sexes of 10 or 11 inches, *i.e.*, from 58 to 68 inches in the females, and from 61 to 72 inches in the males, the absolute increase is much less in the women than in the men, the quantities being, as regards the entire encephalon, 1.17 oz. and 2.59 oz. respectively. In this comparison, of course, the males selected have an actually higher stature than the females selected ; but, if we take an equal range at similar statures in the two sexes, *viz.*, from 58 to 66 inches, the absolute increase in the encephalon in the females is .52 oz. and in the males .9 oz. As to the cerebrum and cerebellum, considered separately, the former organ shows a somewhat greater tendency than the latter to an absolute increase in the taller women, as compared with the increase in the taller men, being $\frac{1}{3}$ th and $\frac{1}{3}$ th of the absolute weights at the lowest stature, instead of $\frac{1}{2}$ nd and $\frac{1}{3}$ th.

Furthermore, the fact is apparent, from the stature-ratios in this table, that the weight of the encephalon and its parts diminishes, in the insane women as in the insane men, relatively

to the stature, as this last increases. The diminution of the female cerebrum in proportion to the stature, as observed between the heights of 58 and 68 inches, is measured by $\frac{1}{8}$ th part of the stature-ratio at the lower height; whilst that of the cerebellum amounts to only $\frac{1}{24}$ th part of its corresponding stature-ratio. This is for a difference of 10 inches of height, whereas for 11 inches difference in the male, the corresponding quantities were $\frac{1}{11}$ th and $\frac{1}{40}$ th part. Hence, stature had a greater influence in the women than in the men.

It is shown, moreover, by comparing the columns containing the ratios between the weights of the encephalon and its parts, and the stature, in this Table and in Table III., that not only the average stature-ratios given at the bottom of each Table, but the stature-ratios at identical heights of the body, in the two sexes, indicate a greater proportionate weight of brain-substance to every inch of height in the male, than in the female series. This evidently depends upon *sexual differences* in the encephalon and its parts overriding the influence of mere stature; which latter, by itself, ought to induce a lower ratio of brain-weights to the stature in the taller sex. The import of this will not be overlooked. It becomes still more interesting when we observe that this smaller proportion of brain-substance to the stature in the female sex, as compared with the male, chiefly concerns the cerebrum, only slightly the cerebellum, and almost imperceptibly the pons with the medulla, as may be seen on comparing the mean stature-ratios of each organ in the two sexes shown at the bottom of each column.

In conclusion, it is seen that the mean ratio of the cerebrum to the cerebellum is, likewise, smaller in the female than in the male encephalon, being as 7.84 to 1 instead of 8.02 to 1. It is only, as already observed, by referring to the test of the stature-ratio of both organs, that we can say positively that this is owing to a sexual diminution of the cerebrum, and not to a sexual enlargement of the cerebellum; indeed, at average or even identical heights, this latter organ is, relatively to the stature, itself somewhat smaller in women, so that to establish a lower cerebro-cerebellar ratio, the cerebrum must be relatively still smaller. In the female, as in the male series, the cerebro-cerebellar ratio diminishes as the stature increases, also owing

to the more marked diminution of the cerebrum, as compared with that of the cerebellum, in the taller women.

As Tables III. and IV. were compiled from observations made upon the insane, and irrespective of age, it seemed to be most desirable to collate, in a similar manner, but also with reference to age, the numerous facts collected by Dr Boyd amongst the *sane*, so that I again applied to him; whereupon, he promptly offered to reduce all the available data in his possession, relating to both the sane and the insane, into suitable tabular forms for the purposes of the present investigation. From the full tabulated results of his labours the following condensed tables have been derived.

TABLES V. and VI.

Tables showing the average weights of the encephalon and its parts, at seven decennial periods of adult life, from twenty years to eighty years and upwards, in 1150 *sane* persons, viz.,

Males.

Total No. of Cases.	Ages.	Stature 69 Inches and over.					Stature 68 to 69 Inches.					Stature 65 Inches and under.				
		No. of Cases.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	No. of Cases.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	No. of Cases.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.
82	20-30	14	48.1	42	5.1	1	28	49.1	42.6	5.3	1	15	46.1	40	5.2	9
60		10	46.1	41.5	5.3	1.1	28	50	43.6	5.4	1	32	47	40.9	5.1	1
94	30-40	23	50.7	44.3	5.4	1	48	47.6	41.8	5	1	28	47.6	41.9	4.7	9
100		29	48.9	42.2	5.6	1.1	41	47	40.8	5.2	1	30	45	38.9	5.1	1
116	40-50	28	46.5	42.4	5.2	9	56	47.6	41.4	5.2	1	32	46.2	40.2	5.1	9
70		30	47.3	40.7	5.5	1.1	31	45.5	39.1	5.4	1	9	43.1	37.1	4.9	1.1
108	50-60	24	47.2	41.9	5.2	1	47	46.6	40.8	5.1	9	32	45.7	39.9	4.9	9
60		23	48.5	42.1	5.3	1.1	27	46	39.8	5.2	1	10	46.8	40.7	5.1	1
118	60-70	31	47.9	43	4.9	1	57	46.8	40.8	5	1	36	45.4	39.6	4.9	9
62		17	47.5	41	5.4	1.1	30	46.7	40.6	5.1	1	15	45.7	39.9	4.8	1
92	70-80	16	48	42.1	4.9	1	41	45.9	40	4.9	1	35	45.9	38.4	4.6	9
34		6	48.5	42.1	5.4	1	22	46.5	40.5	5	1	6	44.8	38.5	5.2	1.1
23	80-90	5	43.4	38.3	4.4	7	10	46.4	40.5	4.9	1	8	46.2	39.4	4.9	9
14		4	44.9	39	4.8	1.1	4	43.4	37.4	5	1	6	44.5	38.7	4.7	1.1

598 *males* and 552 *females*, and in 725 *insane* persons, viz., 400 *males* and 325 *females*, being a total of 1875 persons, arranged vertically in three groups, according to certain selected heights, viz., the males, in groups measuring 69 inches and upwards, 68 to 66 inches, and 65 inches and under, and the females, in groups measuring 64 inches and upwards, 63 to 61 inches, and 60 inches and under. The tables also show the number of cases examined under each head. The figures relating to the sane are in upright Roman type, those relating to the insane in Old Style type. (Reduced from a table constructed by Dr Boyd from data observed in the St Marylebone Infirmary and the Somerset County Lunatic Asylum.)

Females.

Total No. of Cases.	Ages.	Stature 64 Inches and upwards.					Stature 63 to 61 Inches.					Stature 60 Inches and under.				
		No. of Cases.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	No. of Cases.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	No. of Cases.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.
62	20-30	18	41.4	38.9	4.7	.8	32	42.6	36.8	4.9	.9	12	41.5	35.9	4.7	.9
42		17	43.3	37.4	4.9	1	13	41.1	35.6	4.5	1	12	37.9	32.7	4.2	1
71	30-40	26	44.8	39.3	4.7	.8	30	43.4	37.7	4.8	.9	15	42.9	37.5	4.6	.8
36		14	42.7	37	4.7	1	16	42.7	36.7	5	1	6	44.9	38.9	5	1
81	40-50	32	42.5	37.1	4.6	.8	35	42.9	37.4	4.6	.9	14	43	37.4	4.7	.9
79		30	41.9	36.3	4.6	1	33	43.2	37.3	4.9	1	16	42.2	36.7	4.5	1
90	50-60	32	42.8	37.2	4.7	.9	35	42.8	37.3	4.6	.9	23	42.3	37	4.5	.8
59		21	44.8	38.9	4.9	1	22	41.9	36.3	4.7	.9	16	41.5	36.2	4.3	1
128	60-70	45	42.7	37.3	4.6	.8	52	42.6	37.2	4.5	.9	31	42.4	37	4.5	.9
71		29	42.5	36.8	4.7	1	26	43.5	37.7	4.8	1	16	42.5	36.7	4.8	1
56	70-80	26	41.3	35.9	4.6	.8	15	40.4	35	4.5	.9	15	40.7	35.6	4.3	.8
25		8	43.7	37.9	4.8	1	8	42.3	36.4	4.8	1.1	9	40.8	35.5	4.4	.9
64	80-90	18	40.9	35.6	4.4	.9	18	39.4	34	4.6	.8	28	39	33.7	4.4	.9
13		1	44.5	38.5	5	1	17	40.2	34.5	4.8	.9	5	38.5	33.2	4.2	1

These two rather copious tables contain much valuable information in a condensed form. They supply materials for certain comparisons between the insane and the sane ; and in regard to the latter, they not only serve to confirm certain con-

clusions already arrived at, and stated in the preceding pages, but they furnish a series of approximately accurate weights, with which to compare the brain-weights of any given individual of either sex and of any age and height, and they also enable us to proceed to isolate the separate influences of sex, age, and stature on the weight of the encephalon and its parts, in a sufficient number of cases of sane persons to render the results reliable.

For these latter purposes, however, the tables may be still further condensed, by arranging their numerous data into three groups corresponding with the ages, instead of seven—viz., one containing the data relating to persons between twenty and forty years of age, when the brain has reached its prime; a second, those relating to persons between forty and seventy years of age, during which period the brain gradually declines in weight; and a third, those relating to persons beyond seventy years of age, in whom the brain has become actually senile. The following tables are the result.

TABLES VII. and VIII.

Tables showing, in the sane and the insane of both sexes, the average weights of the encephalon and its several parts,

Males.

Total No. of Cases.	Agea.	Stature 69 Inches and upwards.				Stature 68 to 66 Inches.				Stature 65 Inches and under.			
		Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.
146	20-40	49.72	43.43	5.29	1	47.99	41.9	5.09	1	46.95	41.15	4.9	.9
160		48.69	42.02	5.57	1.1	48.18	41.9	5.28	1	45.84	39.74	5.1	1
337	40-70	48.15	42.1	5.09	.96	47.08	41.01	5.1	.97	45.74	39.88	4.96	.9
192		47.74	41.23	5.41	1.1	46.03	39.8	5.23	1	45.32	39.39	4.91	1.02
115	70-90	46.92	41.19	4.8	.93	46	40.1	4.9	1	44.15	38.6	4.65	.9
48		47.06	40.86	5.16	1.04	46.02	40.02	5	1	43.98	36.93	4.95	1.1
598	90-99	48.40	42.34	5.09	.97	47.13	41.08	5.06	.99	45.61	39.84	4.87	.9
400		48	41.46	5.44	1.1	46.86	40.65	5.21	1	45.31	39.27	5.02	1.02

arranged in three horizontal divisions corresponding with certain periods of life, and three vertical divisions corresponding with certain differences of stature. The figures relating to sane are, as before, in Roman, and those relating to the insane in Old Style type. (Reduced from Tables V. and VI.)

Females.

Total No. of Cases.	Ages.	Stature 64 Inches and upwards.				Stature 63 to 61 Inches.				Stature 60 Inches and under.			
		Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.
133	20-40	44.64	39.14	4.7	.8	42.98	37.28	4.85	.9	42.26	36.78	4.64	.84
78		43.03	37.22	4.81	1	41.37	36.20	4.77	1	40.24	34.77	4.47	1
209	40-70	42.67	37.21	4.63	.83	42.75	37.29	4.66	.9	42.49	37.08	4.54	.87
209		42.87	37.16	4.71	1	42.94	37.16	4.81	.97	42.07	36.54	4.53	1
120	70-90	41.18	35.77	4.52	.84	39.84	34.45	4.55	.84	39.59	34.26	4.36	.87
38		43.78	37.96	4.82	1	41.31	35.51	4.8	1	40.04	34.75	4.36	.93
552	20-90	42.76	37.82	4.62	.82	42.87	36.84	4.64	.89	41.58	36.17	4.5	.86
325		42.98	37.24	4.74	1	42.54	36.74	4.8	.98	41.28	35.81	4.49	.98

The average weights in these tables have been obtained, not by simply combining those in the fuller tables, but by multiplying the weight, in each case, by the number of brains examined at that weight, adding the products thus obtained, and dividing the totals by the total number of brains examined in the entire group. The general averages, shown in the two bottom lines, of the absolute weights of the several parts at all ages, from twenty years upwards, have been arrived at in a similar manner.

In order fully to utilise the information contained in Tables VII. and VIII., it was necessary to ascertain the stature-ratios of the encephalon and its parts, which is done, as before, by dividing the average weights of those parts by the mean heights in inches, in each of the three groups. It has been found by Dr Boyd, and I have verified his conclusions, that the three

groups of males, 70, 67, and 63 inches, and the three groups of females, 65, 62, and 59 inches, may be accepted as practically representing the mean heights of the individuals in the six several groups respectively. The following interesting tables of stature-ratios are the result.

TABLES IX. and X.

Tables showing the encephalic stature-ratios, or ratios of the weights of the encephalon and its parts, to the stature in 1857 persons, male and female, sane and insane, the same as those to which Tables V. to VIII. relate. They are arranged, as before, in three horizontal divisions according to age, and three vertical divisions according to the stature. The cerebro-cerebellar ratios are also given at each age, and at the several heights. Lastly, at the bottom, are the general ratios at all ages at the different heights. Roman and Old Style figures are again employed to distinguish the sane from the insane.

Males.

Ages.	Stature 69 In. and upwards. Ratios of Weight to every Inch.					Stature 68 to 66 Inches. Ratios of Weight to every Inch.					Stature 65 In. and under. Ratios of Weight to every Inch.				
	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	Ratios of Cerebrum to Cerebellum.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	Ratios of Cerebrum to Cerebellum.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	Ratios of Cerebrum to Cerebellum.
20-40 {	·710	·620	·075	·014	8·2-1	·716	·625	·076	·015	8·2-1	·737	·653	·07	·014	7 -1
	·695	·600	·079	·016	7·5-1	·719	·625	·078	·015	7·9-1	·726	·630	·08	·016	7·8-1
40-70 {	·688	·601	·073	·014	8 -1	·702	·612	·076	·014	8 -1	·725	·633	·078	·014	8·1-1
	·682	·589	·077	·016	7·6-1	·687	·594	·078	·015	7·6-1	·719	·625	·078	·016	8 -1
70-90 {	·670	·588	·068	·013	8·5-1	·686	·598	·073	·015	8·2-1	·699	·612	·073	·014	8·3-1
	·672	·583	·073	·014	7·9-1	·686	·597	·074	·015	8 -1	·681	·586	·078	·017	7·4-1
20-90 {	·691	·605	·072	·014	8·3-1	·703	·613	·075	·015	8·1-1	·723	·632	·077	·014	8·1-1
	·685	·592	·077	·015	7·6-1	·699	·606	·077	·015	7·8-1	·718	·623	·079	·016	7·8-1

Females.

Age.	Stature 64 In. and upwards. Ratios of Weight to every Inch.					Stature 63 to 61 Inches. Ratios of Weight to every Inch.					Stature 60 In. and under. Ratios of Weight to every Inch.				
	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	Ratios of Cerebrum to Cerebellum.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	Ratios of Cerebrum to Cerebellum.	Encephalon.	Cerebrum.	Cerebellum.	Pons, &c.	Ratios of Cerebrum to Cerebellum.
20-40	·686	·602	·072	·012	8·3-1	·697	·605	·078	·014	7·7-1	·715	·623	·078	·014	7·9-1
	·661	·572	·074	·015	7·7-1	·676	·583	·077	·016	7·6-1	·662	·572	·074	·016	7·7-1
40-70	·655	·572	·071	·012	8 -1	·688	·601	·073	·014	8·1-1	·718	·628	·078	·014	8·1-1
	·658	·571	·072	·015	7·8-1	·680	·597	·077	·015	7·7-1	·711	·619	·076	·016	8 -1
70-90	·632	·550	·069	·013	7·9-1	·641	·555	·073	·018	7·6-1	·659	·572	·073	·014	7·9-1
	·673	·584	·074	·015	7·8-1	·665	·572	·077	·016	7·4-1	·661	·572	·073	·016	7·9-1
20-90	·657	·574	·071	·012	8 -1	·682	·594	·074	·014	7·9-1	·713	·613	·078	·014	8 -1
	·660	·572	·073	·015	7·8-1	·685	·592	·077	·016	7·6-1	·696	·606	·074	·016	7·9-1

In examining the preceding six tables, from V. to X. inclusive, I may, by a slight digression, first dispose of certain contrasts which they present between the sane and the insane.

Although Parchappe found that in the cases of insanity which he first examined, the brain was on the whole larger than in the sane in both sexes, but especially in men, he subsequently detected the fact that in advanced forms of insanity, the brain became smaller than in the sane at corresponding ages. Dr Skae, again, found that the brain-weight in the insane was greater than in the sane. Dr Thurnam and others, even Parchappe himself, endeavour to explain these discrepancies by reference to the influence of different forms of insanity, differences of class, and other causes. Dr Skae, in particular, pointed out that the weight of the cerebellum was often increased in insanity, and attributed the increased weight of the entire encephalon to this circumstance; but, in the weight of the cerebellum, he included that of the pons with the medulla oblongata. Since, however, the question of the influence of stature has been by these and all other observers disregarded, or rather uninvestigated, some interest, it will be admitted, attaches to an examination of the subject with this additional aid to the research.

In Tables V. and VI. it is seen that, in the 42 instances of comparison between the sane and the insane, of corresponding mean stature as well as of corresponding mean age, in the two

sexes, the cerebrum is smaller in the insane in 26 instances, whilst the cerebellum is larger in the insane in 31 instances. In regard to each organ there are a few examples of equality, or of a very close approach to it. The pons and medulla are larger in the insane in 34 instances, and equal to those of the sane in the remaining 7 instances. The entire encephalon is just as frequently larger as it is smaller in the 42 instances.

Again, in Tables VII. and VIII., in the 18 instances of comparison therein contained, it is seen that in the insane, as contrasted with the sane, the cerebrum is smaller in 14 and equal in 1; the cerebellum is, on the contrary, larger in 13 and equal or almost so in 3; the pons with the medulla is larger in 16 and equal in the other 2; and, lastly, the entire encephalon is smaller in 10, equal in 1, and larger in the remaining 7. Moreover, if we compare the results of the six pairs of total averages in the bottom lines of these two tables, the insane cerebrum is the smaller in all 6 instances; the insane cerebellum is the larger in 5 instances, and almost equal in 1; the insane pons and medulla is larger in all instances; and the insane entire encephalon is smaller in 4 instances out of the 6.

Now, as the mode in which these data have been obtained includes a classification of all the cases, both sane and insane, according to stature, it is certain that we may now conclude, without the fear of being deluded by any fallacy attributable to its influence, that in a given number of persons dying afflicted with all the various forms of insanity, the cerebrum is more commonly smaller, the cerebellum still more frequently larger, and the pons with the medulla almost invariably larger, and never less, than in the sane condition. As to the entire encephalon, this is smaller or larger with nearly equal frequency.

The stature-ratios of the several parts of the encephalon, and of the encephalon itself, given in Tables IX. and X., are necessarily quite accordant with these conclusions; but they, moreover, serve to correct any erroneous inferences which might be formed from a comparison of the cerebro-cerebellar ratios, at the different periods of life, and at the different heights of the body, in the sane and the insane. These last-named ratios show, for example, that, with three exceptions, the proportion of cerebrum to cerebellum is invariably smaller in the insane than

in the sane; in two of these cases of exception it is equal, and in one only is it less. In the general averages recorded at the bottom of the table, it is seen that in the males the cerebro-cerebellar ratio ranges in the sane from 8.1 to 8.3 to 1, and in the insane from 7.6 to 7.8 to 1; in the females, the same ratio varies from 7.9 to 8 to 1, whilst the insane ratio ranges from 7.6 to 7.9 to 1. But it is obvious that this difference in the ratios may be otherwise expressed, viz., that the proportion of cerebellum to cerebrum is larger in the insane. In by far the greater number of the instances noted in the tables, it is undoubtedly due to opposite deviations as to size in both of the organs concerned. By comparing their respective stature-ratios, in the sane and the insane, it is, however, at once made plain that, considering the size of each organ, the cerebellum is increased in insanity far more than the cerebrum is diminished, the former organ being increased, on a general average, by about $\frac{1}{25}$ th part of its weight in the males and by $\frac{1}{35}$ th part in the females, and the latter organ being diminished by about $\frac{1}{65}$ th part of its weight in the males and by $\frac{1}{143}$ th part in the females. The male cerebellum, therefore, as thus tested, increases more than the female cerebellum, whilst the male cerebrum diminishes more than the female cerebrum, under the influence of insanity generally. Hence, as is seen on consulting Tables IX, and X., the cerebro-cerebellar ratio deviates more from the healthy standard in the male series than in the female series of the insane.

The further prosecution of this subject I have left in the hands of specialists; but it may be here stated generally, that an analysis of the MS. data, from which I constructed Tables III. and IV., shows that in mania and recurrent mania the cerebrum is, on an average, larger than normal; in melancholia it is slightly above the normal size; whilst in general paralysis, dementia, and fatuity it is below the average. In epilepsy it is below the normal in the males, but above it in the females. On the other hand, the cerebellum is, in all forms of insanity (excepting in fatuity in the males only), larger than in the sane, but especially so in mania, recurrent mania, and melancholia; it is likewise so, in general paralysis and dementia, and even in fatuity in the females. The entire

encephalon is heavier only in mania, recurrent mania, and melancholia. Dr Boyd's more complete analyses of his data will, I believe, confirm these conclusions.

The digression which I have been tempted to make has brought out facts which serve in part to explain the discrepancies amongst the different observers above alluded to, as to the weight of the entire brain in insanity. The effects of difference of nationality, class, and education may explain the rest. It is certain that the test of stature, or the correction dependent on the stature equation, as applied herein to the insane generally, should be also applied to persons labouring under the different kinds of insanity. In reference to the former, it proves most conclusively that any observed increase in the weight of the entire encephalon in the insane is not due to an increase in the cerebellum only; for, on consulting even the full Tables V. and VI., it will be found that in the instances in which this is the case, the cerebrum is, with only two trifling exceptions in the other direction, itself larger than in the corresponding group of the sane. As to the unequivocal evidence of deviations in the cerebrum and cerebellum of the insane, shown even when the effects of stature are duly considered and allowed for, they would seem to be of the greatest interest. The cerebrum, the organ of the higher mental faculties, becomes somewhat larger or heavier in the acute forms of madness; whilst in the chronic or exhaustive forms of insanity it becomes smaller or lighter. How far this is a physiological or a pathological deviation is for inquiry elsewhere. With regard to the cerebellum, it at least never loses weight or size in insanity; but, as a rule, and in all forms of mental disorder, and especially in the more active forms, it is even much enlarged. Has this a physiological or a pathological significance? If physiological, does this indicate some possible association of the cerebellar functions with our emotional as well as with our co-ordinated motorial activities? May its preponderance over the cerebrum precede and so imitate certain forms of insanity; and may this suggest the groundwork of preventive, corrective, or curative treatment, by the employment of strictly intellectual training on the one hand, and of simple corporeal exercises on the other, so as to check or divert the

action of the over-developed or over-developing cerebellum? If pathological, does this indicate a relatively greater amount of chronic inflammation and condensation of the neuroglia of the cerebellum than of the cerebrum.

Reverting now to the general consideration of the facts recorded in the Tables V. to X., in which the influence of stature is specially eliminated from that of age and sex, it may be noted, in the first place, that, as the ascertained mean stature in the male sex is about 66·5 inches, and that in the female sex about 62 inches, it follows that in each of these tables, the central group of the vertical series contains, as nearly as may be, the normal weights and normal stature-ratios of the encephalon and its parts, and the normal cerebro-cerebellar ratios, for persons of mean stature in the two sexes. This applies equally to the insane and to the sane.

In the second place, if it be desired to test the size of any individual encephalon and its parts, these may at once be compared with the average weights of those organs, given in Tables V. and VI., for persons of corresponding age and stature, according to the sex; and, in this manner, a safer basis is obtained for determining any individual deviation from the normal weights. In the case of the late Mr Grote's brain, for example, this was precisely the test which, being required, could not be obtained. In the third place, an examination of the fuller Tables V. and VI., and of the condensed Tables VII. and VIII., shows at a glance the respective influences of sex, age, and stature, more accurately defined from each other by separating that of stature in the manner already explained, the advantage of which is thereby illustrated. The effects of age, in the two sexes, are traceable by following the perpendicular columns of figures; and those of stature by tracing the corresponding numbers along the horizontal lines. Unless where the cases examined are too few, the progression of the several *absolute* weights vertically and horizontally is very regular. These absolute weights are seen to diminish with age, and also with a decrease of the stature, in the manner already described.

As to the *relative* weights of these several parts, when compared with the stature, or their stature-ratios, which are exhibited in Tables IX. and X., it is not only shown that these

become less at the higher statures in both sexes, but it is also evident that not only are the encephalon and its parts absolutely heavier in the male than in the female, but also relatively heavier in reference to the height of the body; and this is true at all ages and at all heights. Even at equal or nearly equal heights, as, for example, in the male group at 65 inches and under, and the female group at 64 inches and upwards, the relative preponderance of the male encephalon and its parts, as tested by reference to the stature, becomes more apparent; for, in this case, the effect of stature is towards increasing the ratio in the male series, but towards diminishing the ratio in the female series. Another reference to Tables VII. and VIII. will show, moreover, that the encephalon and its parts are also absolutely heavier in the shortest males than in the tallest females, although their actual heights are approximately similar. The sexual character, in fact, overpowers the influences of stature.

It will be observed that as the effect of increasing age is to diminish the brain not only absolutely but relatively to the height of the body, which remains practically unaltered, and as the effect of increasing stature is to increase the brain absolutely, but to diminish it relatively, so the joint effect of increasing age and increase of stature is greater than either of these causes operating by itself. Hence, the lowest proportion of brain to the body is to be found in the tallest and oldest persons of either sex (see the left-hand bottom corners of Tables IX. and X.), and the highest proportion of brain in the shortest and youngest persons (see the right-hand top corners of those tables).

In the fourth place, we may employ the data collected together in the preceding tables, for the purpose of separating and expressing in more precise terms, and indeed numerically, as shown in the following tabular statement, the several effects of sex, age, and stature on the absolute weights of the encephalon and its parts, and on the relative weights of those parts in reference to the body as measured by its height.

(1) *Effects on the Absolute Weights of the Parts.*

On the Encephalon.									
Of Sex.			Of Age.			Of Stature.			
Total Adults at all Ages and Heights.	Males, .	Oz.	Years.	Males.	Females.	Inches.	Males.	Inches.	Females.
		47·05	20-40	48·55	48·29	70	48·4	65	42·76
		42·22	70-90	45·7	40·1	63	45·6	59	41·53
		4·83	...	2·85	3·19	7	2·8	6	1·23
On the Cerebrum.									
Total Adults at all Ages and Heights.	Males, .	41·08	20-40	42·16	37·71	70	42·34	65	37·32
		36·77	70-90	39·96	34·86	63	39·84	59	36·17
		4·81	...	2·20	2·85	7	2·5	6	1·15
		Total Adults at all Ages and Heights.	Males, .	5	20-40	5·09	4·73	70	5·09	65	4·62
4·59	70-90			4·45	4·47	63	4·87	59	4·5
·41	...			·64	·26	7	·22	6	·12
On the Cerebellum.									
Of Sex, Age, and Stature combined.									
			Years.	On the Encephalon.		On the Cerebrum.		On the Cerebellum.	
In Males, . . .			20-40 at 70 inches,	49·72		48·43		5·29	
,, . . .			70-90 ,, 63 ,,	44·15		38·6		4·65	
			Differences, . .	5·57		4·83		·64	
In Females, . . .			20-40 at 65 inches,	44·64		39·14		4·7	
,, . . .			70-90 ,, 59 ,,	39·59		34·36		4·26	
			Differences, .	5·05		4·78		·24	

(2) *Effects on the Weights of the Parts relatively to the Stature.*

On the Encephalon.									
Of Sex.			Of Age.			Of Stature.			
Total Adults of all Ages and Heights.	Males, . .	Oz.	Years.	Males.	Females.	Inches.	Males.	Inches.	Females.
		·706	20-40	·721	·699	63	·723	59	·713
		·680	70-90	·685	·647	70	·691	65	·657
		·026	...	·036	·052	7	·032	6	·056

(2) *Effects on the Weights of the Parts relatively to the Stature*—continued.

On the Cerebrum.										
Of Sex.			Of Age.			Of Stature				
Total Adults of all Ages and Heights.		Oz.	Years.	Males.	Females.	Inches.	Males.	Inches.	Females.	
	}	Males, . .	·617	20-40	·632	·610	63	·632	59	·613
		Females, .	·598	70-90	·599	·562	70	·605	65	·574
		Differences,	·024	...	·033	·048	7	·027	6	·039
On the Cerebellum.										
Total Adults of all Ages and Heights.										
	}	Males, . .	·075	20-40	·077	·076	63	·077	59	·076
		Females, .	·078	70-90	·071	·074	70	·072	65	·071
		Differences,	·002	...	·006	·002	7	·005	6	·005
Of Sex, Age, and Stature combined.										
			Years.	On the Encephalon.	On the Cerebrum.	On the Cerebellum.				
In Males, . . .			20-40 at 63 inches,	·737	·653	·07				
,, . . .			70-90 ,, 70 ,,	·670	·588	·068				
			Differences, .	·067	·065	·002				
In Females, . . .			20-40 at 59 inches,	·715	·623	·078				
,, . . .			70-90 ,, 65 ,,	·632	·550	·069				
			Differences, . .	·083	·073	·009				

Proceeding now to summarise the various results above recorded, it has to be noted, that of the quite obvious increase in the *absolute* weight of the entire and sane encephalon, accompanying an observed increase in stature, the cerebrum, in both sexes, necessarily takes a larger share than the cerebellum. In the males, for example, the total increase in the encephalon at the higher stature amounts to 2·8 oz., *i.e.*, to somewhat more than $\frac{1}{6}$ th of its weight at the lower stature; whereas the increase in the cerebrum alone is 2·5 oz., and in the cerebellum ·22 oz., *i.e.*, less than $\frac{1}{6}$ th and about $\frac{1}{22}$ nd of their respective weights at the lower stature. Or, again, the facts may be thus expressed:—The relative weights of the cerebrum and cerebellum being 8 to 1, the relative increase in the two organs, as above

indicated, is 11 to 1, so that the cerebrum not only absolutely, but even in reference to its own weight, increases rather more with increasing stature than the cerebellum in reference to its weight. In the insane, however, as we have seen, the reverse of this happens, owing chiefly to the exaggerated size of the cerebellum.

But, notwithstanding this increase in the absolute weight of the encephalon and its parts in obedience to an increase of the stature, it is shown, beyond doubt, by reference to the ratios in the second part of the preceding tabular statement, that the increase in the weight of the great nervous centres does not keep pace, *pari passu*, with the stature. On the contrary, there is a gradual and progressive relative diminution in the proportion of encephalon, or brain-substance, to the stature, as this latter itself increases. This condition reminds one of the well-known fact that, in the Vertebrata generally, but especially amongst Mammalia, the brain is proportionally smaller, as compared with the weight of the body, in the larger than in the smaller species, even when these belong to the same or to closely allied genera. This relative diminution in the size of the encephalon in taller individuals of the human race, it will be seen, is equally true, if we take the range of stature in both sexes together, or in either sex separately. It is evident that short persons of either sex have, proportionately to their height, a larger amount of brain than taller ones. Nevertheless, as shown in Tables IX. and X., and in the preceding summary, the proportion of brain to the stature always remains larger in the male than in the female, not only at the mean height or generally in both sexes, but even at corresponding or nearly corresponding heights, as, for example, in short men as compared with tall women; but the shortest women have a higher stature-ratio of brain than the tallest men. With this exception, the sexual superiority in the weight of the brain in the male, speaking generally, overrides the influence of stature—*i.e.*, it subsists in spite of his greater stature, which in itself would have a tendency to be associated with a proportionately smaller amount of brain.

Further comparisons show that the stature-ratio of the cerebrum diminishes less markedly and less uniformly than

that of the cerebellum, which latter organ, as already remarked, at least in the sane, obeys the influence of stature more exactly and implicitly, so far as regards its relative proportion to the weight of the body.

Enough has now been stated to show that unless the variations in the brain-weight accompanying differences of stature be eliminated or allowed for, no estimates of the effect of any other conditions which may influence the weight of the encephalon in Man, such as sex, age, race, occupation, education, mental qualities, or disease, can be regarded as altogether free from error. From this point of view many questions require to be reinvestigated; for, by such a method only can it be demonstrated what are the real effects of these and any other modifying causes.

The results above recorded would appear to indicate that, adopting the simplest numbers possible, the difference in absolute weight determined by sex, in the entire encephalon, is about $4\frac{1}{2}$ oz., or 10 per cent.; by age, as a mean in the two sexes, about 3 oz., or 6 per cent.; and by stature, as a mean in the two sexes, about 2 oz., or 4 per cent. It would seem, however, that the effects of age are more evident in women than in men, and that those of stature are more marked in men than women; the quantities in the former case being about $2\frac{3}{4}$ oz. and $3\frac{1}{4}$ oz., and in the latter about $2\frac{3}{4}$ oz. and $1\frac{1}{4}$ oz. The range of difference of stature in the two sexes is different, and, of course, this will partly account for its difference of effect on the male and female encephalon.

As to the weight of the cerebrum, the influences upon it of sex, age, and stature are similar to those which they exercise on the entire encephalon, that of age being more marked in women, and that of stature in men. But in reference to the cerebellum, the effect of age is much more marked in men than in women. Nevertheless, the joint effect of age and stature is greater in men, not only on the weight of the entire encephalon, but also on the weights of the cerebrum and cerebellum separately considered.

Moreover, on comparing the stature-ratios of these several organs, in the two sexes, at different ages, and at different heights, it is shown that, in regard to the entire encephalon;

these ratios are more influenced by age, in each sex, than they are by sex itself; and this is true of the stature-ratios both of the cerebrum and the cerebellum. Thus, the sexual differences of these ratios are, as regards the entire encephalon, as .706 oz. in the male to .680 oz. in the female; whilst the variation due to age is, in the male, as .721 oz. to .685 oz., and in the female as .699 oz. to .647 oz. Finally, the differences attributable to stature are as .723 oz. to .691 oz. in the male, and as .713 oz. to .657 oz. in the female; that is also greater than those due to sex, and about equal to those dependent on age.

It is obvious that other combinations of causes affecting the brain-weight might here be recorded, as, for example, the effects of age at different heights, in both sexes; and, again, the effects of stature at different ages, in both sexes. But these could only be properly appreciated by employing very large numbers of observations. For there remains one other most important element of variation in the weight of the great nervous centres, which, in individual cases, and even as rendered apparent by the study of a very small number of instances, overpowers all other influences, and this is the proper tendency of the encephalon to vary in its developments as to size, in different persons. This residual peculiarity or deviation in the weight of the encephalon and its parts, especially of the cerebrum, in Man, might be called the *proper weight-variation*, or the *personal equation* of the weight of the brain or of the mere cerebrum; considered as an independent or quasi-independent organ.

It is a fact of the highest interest and importance that this personal difference, which can itself be duly estimated only when other conditions, whether of stature, age, sex, or race, are previously allowed for, is far larger, as will be immediately shown, than any of the variations already discussed. There exist, in fact, children with larger brains than many adults; there are certain women possessed of much larger brains than certain men; and there are certain short persons, both male and female, who have larger brains than certain tall ones; there are, indeed, some short women who have larger encephala than some taller men. Moreover, these individual peculiarities are equally observable in reference to the stature-ratios as well as in regard to the absolute weights of the brain and its several parts.

In order to estimate with some precision this most important condition, viz., the proper weight-variation, or individual tendency to variation in the weight of the encephalon and its parts, I will introduce here certain data also furnished me by Dr Boyd, arranged in the following tables.

Table showing the weights of the heaviest and of the lightest brains met with among 648 males and 698 females at 13 quinquennial periods of life. There are recorded, therefore, the weights of 26 selected male encephala, and of 26 selected female encephala. The numbers of persons from which the selection was made, at each period of life, averaged about 50. The heights of the corresponding individuals are also shown. (From the St Marylebone Infirmary.)

TABLE XI.

Agea.	MALES.				FEMALES.			
	Heaviest Brains.		Lightest Brains.		Heaviest Brains.		Lightest Brains.	
	Weight in Oz.	Height in In.	Weight in Oz.	Height in In.	Weight in Oz.	Height in In.	Weight in Oz.	Height in In.
20-25, . . .	54	68	39·2	64	46·8	66	35·6	62
25-30, . . .	57	69	41·5	65	45·8	63	35·7	48
30-35, . . .	57·2	66	33·7	65	48	68	36	61
35-40, . . .	*60·7	69	38·7	67	52	69	37·8	64
40-45, . . .	60	73	37·2	65	52·5	66	37	62
45-50, . . .	54	72	33·7	65·5	48·7	65	36·7	59
50-55, . . .	59	69	39	58	52·5	62	34·3	60
55-60, . . .	57	65	†30·5	68	51	64	37·7	61
60-65, . . .	59·5	68	38·5	66	*54	61	32·5	62
65-70, . . .	57·5	71	36·2	64	48	61	32·7	62
70-75, . . .	52·5	68	36	63	49·2	66	†29·3	48
75-80, . . .	55·2	72	37·7	67	49·5	62	35·7	61
80, &c., . . .	53·2	68	41	70	48	66	33·3	62
Averages, .	56·6	69	37·3	64·8	49·3	64·5	35	59·5

* Heaviest brains.

† Lightest brains.

This table brings out in strong relief the individual element of variation in the weight of the brain, irrespective of the effects

of sex, age, or stature, showing clearly that, after all, this is the chief cause of the remarkable extremes of difference met with in the size of the human brain, and prominently displaying the comparative independence of that organ, as regards the bodily frame, in Man.

Thus, the extreme variation in the male series, according to the table, was from 30·5 oz. to 60·7 oz., *i.e.*, about 30 oz., or as 1 to 2; whilst in the female series it was from 29·3 oz. to 54 oz., *i.e.*, about 24·5 oz., or as somewhat less than 1 to 2. But, if we take the averages of the greatest and least weights, in each sex, at all ages, as shown at the bottom of the table, the range of variation in the 26 males was from 37·3 oz. to 56·6 oz., *i.e.*, 19·3 oz.; and in the 26 females from 35 oz. to 49·3 oz., *i.e.*, 14·3 oz. The great importance of these differential quantities is obvious, when we recall to mind that the sexual difference is 5 oz., that due to age about 3 oz., and that attributable to stature only about 2 oz.

The preceding figures further indicate that the individual tendency to variation in the brain-weight is greater in men than in women, the former sex being perhaps more subject to powerful disturbing agencies than the latter, which might be calculated to create and perpetuate such a distinction, in the shape of mental training, culture, exercise, and trial. As the range of stature in the males averaged 4·2 inches ($69 = 64·8$), and in the females 5 inches ($64·5 = 59·5$), it is obvious that not only does the male brain vary more than the female in its absolute weight, but also relatively to the stature.

The average stature-ratio, expressed as before in decimal parts of an ounce to 1 inch of the height, is, for the 13 heaviest male brains, ·82 oz., and, for the 13 lightest male brains, ·575 oz.; again, for the 13 heaviest female brains it is ·765 oz., and for the 13 lightest female brains it is ·59 oz. These results show that, not only as regards absolute weight, but also as regards the stature-ratio, the male brain varies more than the female brain, the amount of variation in the former being ·245 oz. and in the latter only ·175 oz.

It is obvious that the amounts of the different stature-ratios just mentioned, are regulated by the great and preponderating influence of the individual heaviness or lightness of the series of

brains here arranged together ; so that in fact, certain apparently anomalous results are arrived at, viz., that the stature-ratio in the lightest male brains is less than in the heaviest female brains in the proportion of .575 oz. to .765 oz., although the stature is somewhat greater in the former series ; and, again, the stature-ratio in the lightest female brains is somewhat greater than in the lightest male brains, .59 oz. to .575 oz., although the average stature in the former is really more than 5 inches less. But, it may easily be shown that, even in regard to these small numbers of selected cases, stature has exercised its own peculiar influence, as witness the following table relating to the same cases.

TABLE XII.

Table showing the stature-ratios of 13 heavy and 13 light male brains, and of 13 heavy and 13 light female brains, arranged in groups according to the stature of the individuals.

MALES.				FEMALES.			
Heaviest Brains.		Lightest Brains.		Heaviest Brains.		Lightest Brains.	
Height in Inches.	Stature-ratio.	Height in Inches.	Stature-ratio.	Height in Inches.	Stature-ratio.	Height in Inches.	Stature-ratio.
73	.822	70	.585	69	.753	64	.584
72	.77	67	.576	67	.632	62	.566
71	.838	66	.582	66	.75	61	.6
69	.844	55	.582	65	.75	60	.571
68	.830	64	.60	64	.79	59	.622
66	.867	63	.55	63	.73	48	.676
65	.867	58	.67	62	.836		
				61	.836		

The numbers in this table show clearly that within each group of heavy and light brains, the ratio of the brain-weight to the stature is greater in the shorter than in the taller persons

of each group; and, moreover, that the progressive increase in that ratio from the upper or taller, to the lower or shorter individuals in each column is tolerably regular.

But we may terminate the illustrations of the influence of stature on the brain-weight by another table also derived from Dr Boyd's manuscripts.

TABLE XIII.

Table showing, out of the same 648 males and 698 females, as were made use of in the construction of Table XI, the height of the body and the weight of the brain, in the 13 tallest and the 13 shortest males and females, met with at different quinquennial periods of life. The average number of cases in each group was 50.

Ages.	MALES.				FEMALES.			
	Tallest.		Shortest.		Tallest.		Shortest.	
	Height.	Weight.	Height.	Weight.	Height.	Weight.	Height.	Weight.
20-25	70	48·4	64	46·3	66	46·8	57	39·7
25-30	72	48·7	64	45·9	66	49·3	48	35·7
30-35	72	57·2	50	50·5	68	50·5	54	43·7
35-40	74	53·3	58	55·5	71	41·5	58	42·5
40-45	73	53·2	62	47·6	67	39·8	58	44·2
45-50	72	50·9	54	44	67	42	58	39
50-55	74	48·7	58	39	66	40·3	57	47·7
55-60	72	48	60	45	69	41	54	41·5
60-65	74	41·3	60	49·5	67	43	56	38
65-70	72	46	63	50	67	39·6	54	46
70-75	73·5	44·7	62	45·6	69	49	48	38·9
75-80	72	49·7	60	38·5	66	38·2	55	38
80	72	46	62	47·2	67	39·6	54	41·7
Aver.	72·5	48·9	59·75	46·5	67·4	43·1	54·7	41·27

The average heights and weights shown in the bottom line of this table, indicate that the absolute weight of the brain is greater in the groups of tallest males and females than in the groups of shortest males and females. The average weight amongst the tallest males is 48·9 oz., in the shortest 46·5 oz.; whilst the average weight in the tallest females is 43·1 oz., and in the shortest only 41·27. The difference between the two groups of males is 2·4 oz., and that between the two groups of females is only 1·83 oz.; and as the differences in the average statures are shown to be the same, viz., 12·7 inches, it is evident that the range of absolute variation between tall and short individuals, is greater in the male sex, a conclusion quite in harmony with the preceding statements.

On calculating the stature-ratios from the average heights and weights given at the bottom of the table, it is further shown, even in this small number of selected cases, that this ratio is higher in the shortest than it is in the tallest groups of the two sexes. Thus, in the tallest males it is only ·674 oz., but in the shortest it is ·778 oz.; whilst in the tallest females it is ·639 oz., but in the shortest it is ·754 oz. The difference between the highest and lowest stature-ratios, like the difference in the stature itself, being nearly similar in the two sexes, viz., about ·11 oz.

It is here also rendered evident that the average proportion of brain to the height of the body is, as has been already shown, greater in the male than in the female sex, notwithstanding the greater height of the former. This, moreover, is true, both as regards the tallest and the shortest of the two sexes. In the tallest, the male stature-ratio is, in round numbers, ·67 oz., whilst the female stature-ratio is ·64 oz.; in the shortest, the respective ratios are, as we have seen, ·78 oz. and ·75 oz. The mean stature-ratio for the 26 males is ·72 oz., and for the 26 females ·698 oz.

If, finally, we combine these 26 selected male and 26 selected female cases, into as small a number of groups as possible, corresponding with their heights, the following is the result.

TABLE XIV.

Table showing the stature-ratios of the brain-weight in 13 tall and 13 short males, and in 13 tall and 13 short females, arranged according to the heights of the individuals.

MALES.				FEMALES.			
Tallest.		Shortest.		Tallest.		Shortes	
Height.	Stature-ratio.	Height.	Stature-ratio.	Height.	Stature-ratio.	Height.	Stature-ratio.
74	·645	64	·720	71	·584	58	·716
73	·668	63	·793	69	·655	57	·768
72	·702	62	·788	68	·742	56	·68
70	·691	60	·755	67	·698	55	·69
		58	·814	66	·661	54	·813
		54	·814			48	·801
		50	1·05				

A glance down the columns of this table shows, that the stature-ratios, even in this small number of cases, are greater in the shortest individuals of either sex than in the tallest of that sex; that they indicate, with here and there an exception, a regular increase of the stature-ratios in each group, from above downwards in each column, *i.e.*, in passing from the taller to the shorter individuals of each group; that the male ratios are, nevertheless, higher than the female ratios, although, of course, the heights themselves are greater in the males; and that, with one exception (*viz.*, at the height of 54 inches), if we compare males and females of similar or nearly approximative height, the stature-ratio in the former is greater than the latter.

The numbers of cases included in Tables XII. and XIV., are too small to justify taking them as furnishing more than very interesting illustrations, of the relations between the stature and the brain-weight in either sex, and in the two sexes compared. It will also have been noticed that they relate only to the

weight of the entire encephalon. For more safe average results, we must again refer to Tables V. to X., to the comments on these, and to the summary of results given in pages 471 and 472. It is also from this alone that the modification of the stature-ratios on the cerebrum and the cerebellum can be definitely determined.

II. ON THE RELATION BETWEEN THE BRAIN-WEIGHT AND THE MASS OF THE BODY.

The relations of the brain-weight to the stature, both in males and females, involving the comparison of data which are simple and tolerably exact, having thus been examined, it remains to discuss in the course of this paper the relation which probably exists between the brain-weight and the *mass* of the body in Man. This inquiry will necessitate the employment of more or less hypothetical elements. Of its great interest no doubt can be entertained, especially in reference to a strict comparison between the sexes as to the nobler cerebral endowments.

To decide whether the smaller so-called stature-ratio of the brain in the taller individuals of each sex, should be regarded as a sign of cerebral inferiority in them, and the greater stature-ratio in the shorter individuals, as one of superiority, and, again, whether the smaller stature-ratio of brain in woman, in spite of her lower height, is an indication of her relative cerebral inferiority, in comparison with man, requires a precise knowledge of the relations between the stature and the mass of the human body, in fully grown and well-proportioned persons of different heights, in both sexes.

Speaking generally, yet of standard examples only, the female skeleton and the female body also, being constructed after a more slender pattern than the male skeleton and body, are certainly lighter in proportion to their respective heights; and this may suggest an explanation of the facts that, whilst the difference between the weight of the male and female brain is greater proportionally than the difference between the male and female stature, it is less than the difference between the weight of the male and the female body. As already stated by Parchappe and Thurnam, the statures of the male and female are as 1000 to 932, the ratio of their weights is as 1000 to 872,

and their encephalic ratio is as 1000 to 903; so that, as the last-named observer remarks, the ratio of the female to the male brain-weight is about 3 per cent. less than the ratio of their respective statures, but 3 per cent. more than that of their respective weights. That the woman has less brain in proportion to her height, but more in proportion to her weight, than man, is presumably owing to her mass being less bulky and therefore lighter than man's in proportion to her height. But is not the question herein involved open to a more definite solution?

The larger tables of M. Quetelet, recording side by side the stature and the weight of the human body, relate to individuals of different ages, from birth to the period of complete growth, but not to full-grown persons of different heights. Hence they illustrate only the growth of the human body, male and female, and its mean height and weight in the full-grown condition; whilst they throw no light on the actual variations which exist in stature and weight in individual adults. The mathematical formula invented by Quetelet for deriving the increment of the weight from that of the stature, and the curves, which, according to him, indicate the rate of increase of each, also refer to the case of growing, not of grown individuals. In a special table relating to females only, he places, side by side, the mean weights and heights of a large number of women, in groups according to their ages, from eighteen to forty; but there is evidently no necessary *individual* correspondence between the two series of numbers; so that the information is, only in a limited manner, applicable to the present inquiry. In regard to males, he admits that he has no sufficient data for satisfactory tabulation. Dr Boyd's records of the weight of the body after death are invalidated by the variable effects of different fatal diseases. In Gould's laborious returns concerning the height and weight of the soldiers of the United States army, better materials are to be found; but I prefer to employ those collected by Dr Beddoe, since they relate to inhabitants of the British Isles. I may add that, having examined the complicated methods employed by Krause, Harless, Meyer, and others, for determining the weights of parts of the body in relation to the whole, I do not find them available for the present purpose.

In pursuing this inquiry, I propose to regard the human body

as represented by a *rectangular parallelopiped*, or, as this was named by the late Professor de Morgan for shortness' sake, a *right solid*, supposed to be of uniform density, and having its longest dimension equal to the height of the body itself. In this manner, the mass of any given individual of good proportions, would be reduced to a hypothetical upright four-sided column of correspondent height, bounded by plain surfaces, and having a uniform density or specific gravity throughout.

Suppose, now, that the height of the hypothetical *male* right solid was 66 inches and its weight 138 lbs., or 2208 oz. av., and that the height and weight of the *female* right solid were 62 inches and 117 lbs., or 1872 oz. av., which numbers represent the results of the actual observations of Quetelet, as to the *mean height and weight* of the body in the two sexes, between nineteen and twenty-five years of age; then, on dividing the weight in ozs. by the height in inches in each case, the quotients, 33·4 oz. and 30·2 oz., evidently give the weights of a one-inch thick horizontal portion or slice of the male and female hypothetical right solids. These weights, which I will term the *inch-section-weights* of the male and female, afford a new measure of comparison between the sexes. Their ratio is 1000 to 904, thus, as might be anticipated, falling between the simple stature-ratio 1000 to 948, and the weight-ratio 1000 to 847, obtained from the heights and weights just mentioned and employed in the determination of the respective inch-section-weights, and almost exactly corresponding with the brain-ratio given by Thurnam from Dr Boyd's observations, viz., 1000 to 903. Limiting the comparison between the sexes to average or *mean* examples, it appears therefore that whilst women have 4·5 per cent. less brain in proportion to their stature, and 5·2 per cent. more in proportion to their weight, they have only 1 per cent. less in proportion to the *inch-section-weight of the mass of their body*. Adopting this as a reasonable method of comparison, the sexual difference, as regards cerebral endowments, is shown to be insignificantly small.

It is obvious that the masses of the male and female right solids here imagined, may also be represented by their volumes in cubic inches, in which case, their transverse or *horizontal sections* would be measurable in square inches. Thus, the

weight in oz., multiplied by 1.73, the number of cubic inches in 1 oz. of water, and divided by 1.08, which I have found experimentally to be the specific gravity of the body, would give the volumes of the right solids in question in cubic inches; and these volumes, divided by 66 and 62 inches respectively would give, in each case, the number of cubic inches in each horizontal portion or slice, 1 inch in thickness, and also, of course, the number of square inches in the horizontal sectional area of each right solid. But the ratios of these last quantities in the two sexes, would necessarily be precisely the same as the ratios of their respective inch-section-weights; so that the calculation need not here be further pursued.

The inch-section-weights of the *average* full-grown male and female, viz., 33.4 oz. and 30.2 oz., are, it will be observed, numerically almost equal to one-half the number of inches in the mean stature of each sex respectively. On the supposition that a common, or, as it were, ideal standard of proportional development in Man existed independently of sex, and that, according to this, the inch-section-weight in oz. should exactly equal half the height in inches, *i.e.*, should be 33 oz. and 31 oz. at the mean male and female heights, 66 inches and 62 inches respectively, the numbers just quoted, as derived from the observed mean heights and weights, would be somewhat above such standard in reference to the male, but more decidedly below it as regards the female. Such a result would accord with the fact that the female frame is, even relatively to its stature, smaller than the male frame, and necessarily has, height for height, a smaller horizontal section. Each sex might, as it were, be supposed to deviate, in the progress of its development, from an imaginary intermediate and neutral standard of proportion, in accordance with its special destiny and mode of differentiation, the male keeping very much nearer to it than the female, whose deviation from it, as will presently be shown, is the more remarkable.

The calculations already made, terminated in a comparison between the mean heights and weights of the body, the mean inch-section-weights, and the mean brain-weights of the sexes, as expressed in certain ratios; but, we may now further ask, what are the effects of differences of stature on the weight of

the body, on the weight of the inch-section, and on the weight of the brain, as shown by an examination of these points in groups of individuals of different height, belonging to each sex. In this inquiry, it becomes impossible to employ ratios as tests, since the data are necessarily much fewer in each category or class under examination; but sufficient contrasts may be obtained by resorting to direct comparisons of the observed and calculated quantities, in each case.

As regards the *male* sex, for example, the first part, A, of the following table, compiled from the data collected by Dr Beddoe, shows the *observed* weight of the body in lbs. and in oz., and also the actual inch-section-weight, in men of different heights, from 70 downwards to 62 inches. In the second part of the table, marked B, are given the *calculated* weights of the body, at the corresponding heights, on the supposition, already indicated above, that the number of oz. in each inch-section of the equivalent hypothetical right solid, was exactly equal to half the number of inches in the height.

TABLE XV.—*Males.*

Height in inches.	70	69	68	67	66	65	64	63	62
A. Observed Mean Weights.									
Weight of body } in lbs.,	164	153	147	142	138	133	125	121	?
Weight of body } in oz.,	2632	2456	2352	2280	2208	2128	2000	1936	?
Inch-section- weight in } oz.,	37·3	35·6	34·6	33·9	33·4	32·7	31·2	30·7	?
B. Calculated Weights.									
Weight of body } in lbs.,	153	148·75	144·5	140·25	136	132	128	124	120
Weight of body } in oz.,	2450	2380	2312	2244	2178	2112	2048	1984	1922
Inch-section- weight in } oz.,	35	34·5	34	33·5	33	32·5	32	31·5	31

On comparing the two series of numbers in A and B, it is seen that the calculated results approach very nearly to the results of observation. This is especially observable at the heights of 67, 66, and 65 inches; 66 inches being, as already stated, the mean height or standard proportion of the male sex. At this height, also, it is seen that the weight of the body, and consequently the inch-section-weight derived from Dr Beddow's observations, exactly coincide with those already quoted as obtained from Quetelet's data. Above 67 inches, the observed weight and inch-section-weight rise above, whilst below 65 inches, they fall below the calculated quantities.

The weight of the living human body is, however, a very variable factor, and one exceedingly difficult to determine with accuracy, or to estimate correctly. The popular estimates are usually much too high. Even the naked weight is influenced by the presence of more or less food, and of solid and liquid excreta, which are actually extraneous to the body, regarded as an active machine governed by its nervous centres. Moreover, unless in the case of trained persons, who always lose weight at first, from the diminution of redundant subcutaneous or internal fat, or of persons, like prisoners and others, who are subjected to a scientifically balanced diet and occupation, it may be said that one cannot obtain an observation of the *pure* or *normal* weight of the body. This difficulty may be illustrated by reference to the differences observed in the wild and domesticated condition of any given animal. Again, in such a comparison as that now instituted, the weight of the cerebrum itself might, with propriety, be deducted from the total weight of the body, before the proportion of one to the other should be attempted to be shown. On one or other, or all of these grounds, therefore, it seems to me that all the observed body weights might be reduced somewhat, in which case the slight discrepancy between the *central* or *mean* observed weight at 66 inches, and the corresponding calculated body weight would disappear.

Again, it is not unreasonable to conclude that, as the taller men, in the struggle for existence in a civilised community, would fall into positions requiring more physical labour, the weights of their bodies, as found by Dr Beddow, should have a tendency to be relatively heavier, even in proportion to their

height, as compared with the shorter men, in which class, Dr Beddoe found that most criminals were included, who would either be living a very precarious life, or be fed on prison fare. It, of course, would be expected that the development of the nervous centres would chiefly follow that of the muscular system, next that of the skin and other organs of sensation, and only in a very remote manner that of the viscera; whilst it would have no relation of importance to the growth of adipose tissue, which, on the other hand, would be more likely to abound in well-grown, well-employed, and well-fed men than in their less favoured and very demoralised fellow-creatures.

From these considerations, it would seem justifiable to reduce somewhat the observed weights of the taller men, and increase slightly those of the shorter men, in Dr Beddoe's series, and thus bring each class nearer to the calculated weights. Nevertheless, the taller men would still exceed, and the shorter men fall short of, the herein supposed standard proportion of weight to height. This would coincide entirely with what has already been noticed in comparing the taller body of the male with the shorter body of the female; and it, moreover, agrees with, if it does not explain, the smaller stature-ratio of brain in tall men as compared with short men, which might be regarded as due, not to deficiency of brain, but to excess of body-weight in the former.

On proceeding to make further use of the method of calculation above described, I found, quite unexpectedly, that, in the case of the *central point of stature*, or *mean height* of the *male* body, viz., 66 inches, if the weight of the equivalent right solid in oz. be divided by the number of square inches in its horizontal section, the result gave, within a small decimal part of an oz., the weight, not of the entire encephalon, but of the *cerebrum*, in *males* of corresponding stature. Thus, 66 inches being the height of the hypothetical male right solid, 33 oz. is the supposed weight of each of its transverse inch-sections or slices, and 2178 oz. its total weight (see Diagram A, p. 497). Then 33 ozs., or the inch-section-weight, multiplied by 1·7 (the number of cubic inches in an oz. of water), and divided by 1·08 (the specific gravity of the human body), or, what is the same thing, 33 ozs. multiplied by 1·6, gives 52·8 cubic inches as the

volume of each inch-section, and, therefore, 52·8 square inches as the area of the horizontal section of the right solid in question. But 2178 oz. divided by $52\cdot8 = 41\cdot25$ oz., and on referring to Table VII. in this memoir, compiled from Dr Boyd's observations, it is seen that the average weight of the *cerebrum* in the 598 sane *males*, whose *mean stature* would be 66 inches, is 41·1 oz., showing a difference of only ·15 oz.

This can hardly be considered an accidental coincidence. The result follows from the consideration and use of *mean* or average quantities. The one assumption made in obtaining it, consists in the supposed relation of the inch-section-weight to the height; but the 33 oz. assumed is within ·4 oz. of the observed quantity, and that implies a difference of only 2 lbs. weight in the entire body, which may be owing to error of observation, to excess of fat, or to the inclusion of extraneous matters in the observed body-weight. The numbers would seem to point to a definite relation between the weight of the *cerebrum* and the mass of the body, this mass being expressed by its horizontal section, which is itself dependent on the ratio of its weight to its stature. The importance of the stature as a basis of calculation becomes thus apparent; and it can hardly be doubted that in a well-proportioned man, some definite relation must exist between this and the mass of the body, and also between the latter and the size of the great nervous centres; for, even in the most complex organisms, proportion of parts is never absent.

The following table is designed to show some further results of this method, as applied to estimating the cerebral weight in males of different stature, varying, on either side of the mean height of 66 inches, between the heights of 60 and 70 inches. The observed weights of the cerebrum are placed beneath the calculated weights, in each case.

[TABLE XVI.]

TABLE XVI.—*Males.*

a. Height of body in inches, . . .	72	70	68	66	64	62	60
b. Weight of body in oz., . . .	2592	2450	2312	2178	2048	1922	1800
c. Inch-section weight in oz. of equivalent right solid, }	36	35	34	33	32	31	30
d. Horizontal section in square inches of equivalent right solid, }	57·6	56	54·4	52·8	51·2	49·6	48
Calculated weight of cerebrum, i.e., b divided by d in oz., }	45	43·75	42·5	41·25	40	38·75	37·5
Observed weight of cerebrum from Dr Boyd's data, }	* 43·75	* 43·22	42	41·1	40	39·4	* 38·5

* These numbers are taken from very few observations.

This table shows that, not only at the mean height of 66 inches, but for heights 4 inches above and below that mean, the weight of the cerebrum, as estimated in the manner here employed, agrees very nearly with the results of actual observation. Above that range of stature, however, the calculated cerebral weight is greater than the observed weight, whilst below that range it is less ; in other words, the actual cerebral weight, as thus compared with the mass of the body, regarded from the point of view of its hypothetical horizontal section, is smaller in tall, and larger in short men, a conclusion in harmony with the facts already stated, viz., that the body-weight of tall men is, relatively to their stature, heavier than that of short men, and also that the stature-ratio of their entire encephalon is less.

As regards the *female* sex, no sufficient data exist, from which to ascertain the relations between the stature and the weight, in individuals of different heights ; so that our consideration of those relations must be mainly directed to the case of the *mean stature* and *mean weight* of the full-grown female. According to Quetelet, the mean stature of women, between nineteen and twenty-five years of age, is almost exactly 62 inches. For this height, adopting the same basis of calculation as that employed in the case of the male body, the inch-section-weight would be 31 oz., and the equivalent female right solid would weigh 1922 oz. or 120 lbs. Now this would give, as is seen recorded in the male series in Table XVI., 49·6 square inches for the horizontal sectional area ; and, accordingly, 1922 oz. divided by 49·6, i.e.,

38.75 oz., would be the calculated mean weight of the cerebrum (see Diagram B, p. 497). But the observed mean weight of the female cerebrum, in individuals of mean stature, and at twenty years of age, is 37.23 oz. or 37.8 oz. (see Tables II. and VIII.); so that, on the preceding estimate, the female brain would appear to be, as contrasted with the male brain, deficient in relation to the mass of her body.

It is, however, as before observed, quite certain that the female body is constructed after a lighter model or pattern, and that height for height it weighs less than the stronger male frame. Turning, indeed, to the tables of Quetelet, it is found that the mean weight of women of the mean height of 62 inches, and of the age of twenty years, is 117 lbs., and on the ground of error due to excess of fat, or the inclusion of extraneous matters, it is not unjustifiable to reduce this to 116.25 lbs. or 1860 oz. Now, this would give for the inch-section-weight of the hypothetical female right solid 30 oz., and for the horizontal section 48 square inches. But, again, 1860 oz. divided by 48 yields 38.75 oz., *i.e.*, the same result as before obtained, for the *calculated weight of the corresponding female cerebrum* (see Diagram C, p. 497). It is thus obvious that the method adopted for calculating the weight of the cerebrum in the male, cannot be applied directly to the determination of this factor in the female. The relation between the height and weight of the body, and therefore between the height and the horizontal sectional area, is peculiar or different in the female. As already stated, the female, even at her mean height, deviates thus in a remarkable manner from the male, who may be said to conform, at *his mean height*, exactly to the above assumed standard of proportion of height to weight, and therefore as to horizontal section. This latter quantity in the two sexes, at their respective *mean* statures, 66 and 62 inches, is seen to be as 52.8 square inches to 48 square inches, or as 33 oz. to 30 oz. (see Diagrams A and C, p. 497); but, at a given height in each sex, for example 62 inches, the horizontal sections of *the corresponding right solids* are as 49.6 to 48, or, more simply, as 31 to 30 (see Diagrams B and C, p. 497). But, as $31 : 30 :: 38.75 : 37.5$, which is, therefore, the *corrected calculated* weight of the female cerebrum at the height of 62 inches; this almost exactly agrees

with the results of observation, for it falls midway between the two actually observed weights, viz., 37·23 oz. and 37·8 oz.

Hence, as in man, so in woman, the cerebrum appears to bear a definite relation to the section of the body, if this be regarded as an equivalent vertical right solid, such horizontal section being itself a resultant of the relations of its weight and height. Thus, we are finally led to the conclusion that, although a woman, judged by her height of body alone, has less cerebral matter, and judged by her weight of body alone, has more cerebral matter than man, yet, when both sexes are judged by an assumed common measure, which, in each, has reference to both those factors, their cerebral endowment is seen to be practically equal; so that the discrepancy which appears to exist in their cerebral ratio is thus fairly reconciled. The subjoined tabular statement of the calculated ratios will sufficiently illustrate this.

Calculated Ratios between the Mean Male and Female.

1. Ratio of stature, . . .	66 to 62 in.	1000 to 939
2. Ratio of weight, . . .	2173 oz. to 1860 oz.	1000 „ 854
3. Ratio of inch-section-weight, .	33 oz. to 30 oz.	1000 „ 809
4. Ratio of weight of the cerebrum,	41·25 oz. to 37·5 oz.	1000 „ 909
5. Ratio of stature-ratio to weight-ratio, }	939 to 854 oz.	1000 „ 909

The ratio last enumerated necessarily follows from the first and second, and agrees with the third. The first and second are different from the ratios given from Parchappe; but, in my final judgment, are nearer to the truth as standard or mean numerical results. As to the fourth ratio in the preceding series, it is the most striking of all; it is also different from the corresponding ratio, viz., the brain-ratio recorded in p. 482; but that was *encephalic*, this is *cerebral*. Its coincidence with the sectional ratio stamps it with significance.

The true explanation of the differences as to cerebral endowment and power between the sexes, may possibly therefore be once more remitted to the absolute, rather than to the relative

amount of brain substance possessed by each, a brain mass of 1000, even if associated with a larger corporeal machine, being more vigorous and energetic, as a mental organ, than a brain mass of 909, associated even with a correspondingly smaller body.

It must now be mentioned, lest it should be supposed to be overlooked, that the circumstance of the agreement of the inch-section-weight in oz., with one-half the height of the right solid in inches, is a numerical coincidence, which would have no value whatever, unless it corresponded, as it does, so closely with the *observed* weight of the body divided by the *actual* inches of height. Being so, however, it greatly facilitates the required calculations. The essential relation, however, is that between the sectional area in square inches and the height in linear inches, of a right solid of uniform density; and, I need hardly add, that all the calculations, though in a different manner, can be worked on the metrical system, by the use of centimetres and grammes, as will be presently exemplified.

It is not here asserted, that the preceding method of estimating the normal proportion of cerebrum to the rest of the body is absolutely exact. It is meant only, that the method discloses the existence of a relation between the two things concerned, and serves to illustrate that relation by reference to numbers. Exactitude is at present impossible, and perhaps always will be; for the impulses of organic movements, even if subordinated to a rule capable of a mathematical expression, display ceaseless variety both in time and space.

The deviations from the assumed or calculated relation between the cerebrum and the body, taking place in one direction in tall persons, and in the opposite direction in short persons, so that an ascending line or curve, representing the actual weights, would be crossed by another ascending line representing the calculated weights, necessarily imply the existence of a place of concurrence or centre of true relation, just as the above described lines must intersect; and it is of consequence to note that, the point of coincidence between the observed and the calculated quantities, as recorded, for example, in Table XVI. for the male sex, in which alone they can at present be compared, occurs at or about the point of *mean*

stature for that sex. That the amount of these deviations at other heights may be partly reducible, by taking into account errors of observation, or an excess or deficiency of nutrient material, or of fat in the body, has been already suggested; but two other considerations, then deferred, may here be mentioned. On the one hand, the powerful inherent or intrinsic tendency of the nervous centres, and especially the cerebrum, to vary in size, may, in any individual instance, overbalance the general relation of proportion, in one way or the other; and, on the other hand, the body itself most probably sometimes departs, during the progress of growth, from its originally destined path of development, so that an intended tall man, with full-sized brain, has his stature dwarfed, and an intended short man, with a small-sized brain, has his height increased, by accidental causes, such as constitutional debility, illness, or accident; or, again, what may even more readily happen, persons of intended mean stature, with medium-sized brains, may, in their growth, vary in either direction. To eliminate the effects of such inevitable causes of deviation, a much larger number of observations would be required than are yet at command, of persons occupying the extremes of position as to stature; whereas, these are necessarily fewer than the observations of individuals at or near the mean height.

The following table exhibits the marked tendency of the cerebrum itself to individual variety, or personal equation, at each of the indicated statures.

TABLE XVII.—*Males.*

Heights in Inches, . .		72	70	68	66	64	62	60
Observed Weights of Cerebrum in the Male.	Greatest, . .	48	47	48	47	49	47	46.5
	Mean, . .	48.75	48.2	42	41.1	40	39.4	38.5
	Least, . .	38.25	36.5	36	35	36.5	32.5	34
Calculated averages, ¹ .		48.3	42.23	42	41.08	41.83	39.63	39.66

¹ The author had not filled in the figures of the line of "calculated averages." The figures now inserted express the averages of the weights referred to in Table XVII., but it is possible that the figures 45 | 48.75 | 42.5 | 41.25 | 40 | 38.75 | 37.5 from Table XVI. may have been intended.—A.B.M.

Disclaiming the least desire to overrate the value of any of the preceding results, I will now attempt to show that a table of the estimated mean weights of the *entire encephalon* may be constructed, for persons of different stature, and of either sex from the relations already described as apparently existing between the cerebrum and the body.

It may first be pointed out that, as regards the *male* sex, the calculated weight of the cerebrum in individuals of any given height may be obtained in a less circuitous manner, than that already explained as the one by which this result was originally obtained. For, since the subdivision of the total weight of the hypothetical right solid by the number of square inches in its horizontal section, or *base*, is equivalent to the subtraction from that solid of a vertical column of equal height, and one inch square, *i.e.*, of an upright pile of cubic inches, equalling in number the inches of height, it is merely necessary, in regard to the *male*, to divide the number of inches of height by 1.6, the factor required to convert cubic inches of a substance having the density of the human body, into oz. av., to obtain the sought-for result.

Diagrams of Right Solids.

The annexed diagrams (p. 497) will serve to show this and other relations of the male and female hypothetical right solids described in this paper. As the quantities are marked on each figure, no special references to these are needed.

In figs. A and C, the various quantities are given in French measure also. Thus, 167 centimetres are, as nearly as may be, equal to 66 inches of height; a column of water, 1 square centimetre in horizontal section, and of that height, would contain 167 grammes weight of that fluid; and, as 1.08 is the specific gravity of the human body, 167×1.08 will give the weight of a corresponding column of the equivalent right solid, *viz.*, 180 grammes. But, as there are 6.45 square centimetres in 1 square inch, there would be 6.45 of such columns resting on a base of that size; so that $180 \text{ grammes} \times 6.45 = 1169 \text{ grammes}$, the weight of a column of the right solid, standing on a base measuring 1 square inch, and being 66 inches high; and that would be the calculated weight of the cerebrum in a man of

that stature. In all cases in *males*, therefore, the height in centimetres, multiplied by 1.08, and again by 6.45, or, what is the same, multiplied by 7, gives the estimated weight of the cerebrum in a male of similar height in grammes. It may be added that the calculated English cerebral weight in a male 66 inches high, *i.e.*, of mean stature, *viz.*, 41.25 oz. *av.*, is equal to 1169.4 grammes in French weight. This would give for the entire encephalon a weight of about 1350 grammes, which is a little below the average European weight, about 1380 grammes; but, in estimating this latter, the stature and its effects have not been observed nor allowed for.

Figs. B and C are introduced to show graphically that the mode of estimating the male cerebral weight is not applicable to the female, owing, as already explained, to the different relation between the sectional area and the height of the female right solid, as determined by her smaller total weight, *i.e.*, by her smaller and lighter frame, height for height. Thus it will be seen that, although the sectional area of the female right solid C, is only 48 square inches for a height of 62 inches, whilst the sectional area of the male of similar height is 49.6 square inches; yet, as the weights of these two solids, according to the method employed, are necessarily strictly proportioned to the sections respectively, *viz.*, 1860 and 1922 oz., the division of the two latter quantities by the two former gives the same quotient, *viz.*, 38.75 oz. Indeed, whatever the size of the sectional area, as it always bears the same relation to the weight when the height is equal, that quotient will be the same; and, as that always gives the weight of an identically sized column of the right solid, *viz.*, one of 62 inches high, and 1 square inch in section, it could not properly represent the weight of the corresponding cerebrum under such numerous and widely different conditions. For, let the height be 62 inches, and the inch-section-weight either 30, 20, or 10 oz., then

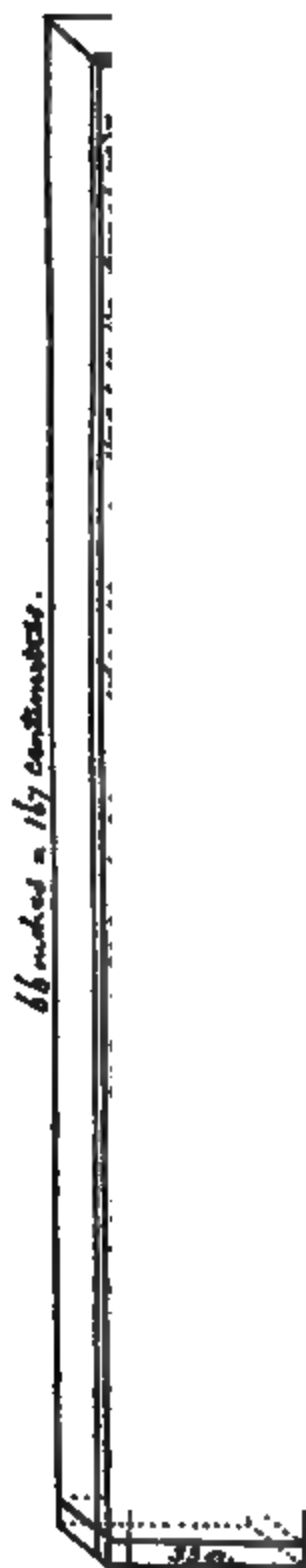
$$\frac{62 \times 30}{30 \times 1.6}, \text{ or } \frac{62 \times 20}{20 \times 1.6}, \text{ or } \frac{62 \times 10}{10 \times 1.6} = \frac{62}{1.6} = 38.75 \text{ oz.}$$

Finally, then, it is seen that, when the inch-section-weight in oz. is half the height in inches, the total weight in oz., divided by the sectional area in square inches, gives the calculated

A. Male. Diagrams of Right Solids.

B. Male.

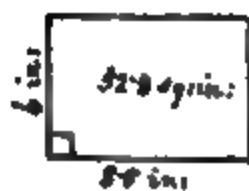
C. Female.



60 inches.



62 inches = 157 centimeters.



weight of the cerebrum in oz., which, moreover, is also equal to the number of oz. in a four-sided column of the right solid in question, measuring 1 square inch in section, *i.e.*, containing as many cubic inches as the solid is high. This is the case in the male right solid of mean height, and with slight deviations, in male right solids of greater or less height. But it is not true of the female right solid. To find the corresponding calculated cerebral weight in that case, the proportion of the sectional area, or of the inch-section-weight, it does not matter which, to that of the male, has to be taken into account, and this will furnish the calculated weight of the female cerebrum. Thus, according as we compare the female of the mean height of 62 inches, with the male of the mean height of 66 inches, or with a male of the same height, viz., 62 inches, we have the following proportions as 33 : 41.25 oz. :: 30 : 37.5 oz., or as 31 : 38.75 oz. :: 30 : 37.5 oz.; in each case, the fourth term is the same, and gives the estimated weight of the female cerebrum at the mean stature. Using English inches for the height, and oz. av. for the weight, the following simple equations are all that are necessary:—

Weight of the mean male cerebrum, . $\frac{\text{Height}}{1.6}$

Weight of the female cerebrum, . . $\frac{\text{Height}}{1.6} \times 30 \div 31$

I here insert one more table, constructed on the bases already stated, to show the estimated weights of the body and of the *entire brain*, or *encephalon*, in full-grown males and females of different stature.

TABLE XVIII.

Heights in Inches, . .		72	70	68	66	64	62	60	58	56
Calculated Weight of Body in lbs.	Males, . . . 1	62	153	144.5	136	128	120	112	...	...
	Females, . . .	...	...	140	131.5	123.5	116	109	101.5	95
Calculated Weight of Encephalon.	Males, . . .	51.6	50.23	48.8	47.35	45.9	44.48	43.05	...	...
	Females, . . .	...	...	47.29	45.87	44.5	43.18	41.72	40.33	39.18
Observed Weight of Encephalon.	Males, . . .	49.75	49.2	48.1	47.8	46.4	45.7	44.7*	...	...
	Females, . . .	...	...	47	45.6	43.9	42.9	41.6	40.54	39.4

* This most discrepant result is taken from too few observations.

In compiling this table, the *calculated* weights of the male and female body are first obtained, and then the calculated weight of the *cerebrum* in each case is determined in the modes already explained. Next, the weights of the cerebellum, and of the pons with the medulla oblongata, are ascertained and added in each instance, so as to obtain the weight of the encephalon, or entire brain. The male cerebellum is supposed to be in the proportion of 1 to 8·1, and the female cerebellum as 1 to 8, in reference to the cerebrum; the pons with the medulla oblongata is assumed to be equal to $\frac{1}{3}$ th part of the cerebellum. As to the *observed* weights of the encephalon at the corresponding heights, these have been obtained from some of Dr Boyd's observations, by taking, where possible, the mean of *three* adjacent groups of brains, always of individuals of from twenty to thirty years of age, and excluding very extreme cases of deficient weight, as a fair representation of the brain-weight of the middle group: thus, the tabulated weights at 66 inches and at 62 inches, for example, are obtained from the weights observed at 67, 66, and 65 inches, and at 63, 62, and 61 inches, respectively. Otherwise, the numbers employed at the required age would have been too few to have obtained tolerably fair results.

The observed and calculated weights correspond most nearly in the centre of each series, male and female; the former, as elsewhere noticed, are slightly defective at the higher, and excessive at the lower statures. The means of each series are as follows:—

Calculated weights—male, 47·34 oz.; female, 43·14 oz.

Observed weights—male, 47·0 oz.; female, 42·93 oz.

The numbers in this table may also be compared with those, at approximate heights, given in Tables VII. and VIII., with which, it will be seen, they show a remarkable concurrence.

Assuming that these results justify their use as a sort of scale of cerebral or encephalic development in Man, according to his stature, it would become possible to assign, more nearly than has yet been done, the proper relative position, as to weight, of any given person's brain, in reference to a certain *standard* or *normal* weight. In other words, its *proper weight-variation* could be at once determined; and this would indicate, so far as

size alone can do so, its individual superiority or inferiority, as compared with other brains.

For example, the observed weights of the brains of the following distinguished men, allowance being made for the effects of age in diminishing the weight in each case, were as follows:—

Thackeray.	De Morgan.	Babbage.	Grote.	Grant.
59 oz.	54·5 oz.	52·5 oz.	52 oz.	48·75 oz.

But the estimated standard weights, according to their respective statures, would have been:—

Thackeray.	De Morgan.	Babbage.	Grote.	Grant.
53 oz.	51·4 oz.	49·5 oz.	51 oz.	50 oz.

Hence, in respect of such standards, the brains of Thackeray, De Morgan, Babbage, and Grote show an excess of weight, or a proper weight-variation of 6 oz., 3·1 oz., 3 oz., and 1 oz., respectively; whilst the brain of Professor R. E. Grant was 1·75 oz. below the calculated weight. Such a mode of comparison is of greater interest, and probably of greater value than one with a mean brain weight, determined without reference to differences of stature, such as those of Boyd, Welcker, and some other observers.

I trust, in conclusion, that however imperfect the present investigation may hereafter be shown to be, it will serve to render more complete our knowledge of the quantitative relations, which must assuredly exist between the brain and the body, *i.e.*, between the governing and governed portions of the human frame.

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A FEW NOTES ON EPITHELIAL PEARLS IN FŒTUSES
AND INFANTS. By A. A. KANTHACK, *John Lucas
Walker Student in Pathology, Cambridge University.*
(PLATE XI.)

(From the Laboratory of the Pathological Institute, Berlin, 1890.)

IN his lectures on "Evolution in Pathology," Mr Bland Sutton (1) alludes to the existence of epithelial pearls¹ in the middle line of the hard palate and in the alveolar processes of the maxillæ of fœtuses and new-born children. He regards them in the "light of epithelial sequestra" or rudimentary dermoids. "As the two epithelial surfaces of the hard palate become fused, epithelial cells are included and remain embedded in the tissues as sequestra." He finds the chief support for this assumption in the investigations of A. Epstein (2) and H. Leboucq (3).

According to Epstein, these pearls are inclusion-products. "In the hard palate they owe their origin to an irregular and in places interrupted union of the palatine processes, between which small hollow spaces remain behind. These develop into epithelial nests or pearls by proliferation of the cells lining them. They are formed during the blending of the two edges, covered by mucous membrane, growing towards one another, or in sinuses and crypts formed by a process of folding, which are subsequently cut off from the surface."

Epstein found these pearls (1) in the posterior portion of the palatine raphé, more or less restricted to the middle line; (2) in the alveolar processes, especially of the upper jaw, in the dental groove; (3) on the anterior surface of the gums; (4) at the lines of reflexion of epithelial surfaces, *e.g.*, nymphæ; (5) in the frænum linguæ; (6) the palatine arches; (7) in the prepuce

¹ These bodies are identical with the laminated onion-like masses often called "nests," which are of frequent occurrence in cancrioid and pachydermia. As the term "nests," however, is also applied to the typical alveoli filled with epithelium, and characteristic of carcinoma, to avoid all confusion the word "pearls" has been consistently used in this paper to denote these well-known concentrically arranged masses of horny epithelium.

at its line of reflexion and in the middle line on its under surface; (8) on the vaginal surface of the cervix uteri. In all these localities they may be seen in most new-born children. The pearls, according to Epstein, are generally surrounded by a fibrous capsule, and separated from the surface epithelium by a stratum of submucous tissue.

Leboucq (*op. cit.*) agrees with Epstein as far as the pearls in the palatine raphé and the palato-intermaxillary suture are concerned. These, he says, are formed "d'une manière passive par l'accolement des surfaces primitivement séparées et l'enclavement du revêtement épithélial qui les recouvrait." The pearls found in the middle line of the abdomen and penis he explains in like manner. He also describes pearls at the sides of the papilla incisiva, which he assumes are due to the cutting off of portions of the foetal naso-palatine duct. The pearls in the alveolar processes, according to Leboucq, are remains of the enamel germ, and "semblent être l'indice d'une activité formative spéciale des éléments épithéliaux de la voûte palatine."

Both Epstein and Leboucq, therefore, regard these pearls in the light of *inclusion products* (Bland Sutton's "sequestration dermoids"). The former, in fact, sees in these pearls a probable support of Cohnheim's inclusion theory.¹

The object of the following brief study was to investigate the origin of these pearls. The first question is, Where do we find epithelial pearls? Besides the localities mentioned by Epstein and Leboucq, in the tonsils of new-born children pearls are constantly found. These I have described elsewhere (4). It may be of interest to mention that similar masses are at times also found in the tonsils of adults and in the hypertrophied adenoid tissue at the basis linguæ (Zungenbalgdrüsen). In the penis pearls were always found, never however on the under surface, as Epstein and Bland Sutton maintain, but always between the glans and the prepuce, centrally or laterally (*cf.* Schweigger-Seydl (5).

¹ Even if Epstein's views were correct, they would be no support of Cohnheim's theory, as there is great difference between embryonic tissue and tissue included during embryonic life (*v.* Virchow, *Cellulärpathologie*, Berlin, 1871, pp. 74-79). "Tissues which already exist in the embryo and in extra-uterine life are preserved as such, are not necessarily embryonic. Embryonic tissue is the immature, incomplete, and transitional tissue of early uterine life."

Histology of the Pearls.—A glance at fig. 2 will teach more than a lengthy description. Here a typical pearl is represented. It is identical in appearance with the concentric bodies seen in cancroids, the cells being, however, somewhat smaller and more closely packed. A fibrous capsule does not exist. Sometimes cornification is so advanced that the pearl forms an apparently homogeneous mass which easily falls out, leaving a hollow space in the section. Cholesterin was never found. In some cases, especially near the papilla incisiva, instead of such a typical pearl we find a large space filled with desquamated and degenerating epithelium (*v.* fig. 3), and the same applies to the large pearls observed at the junction of the hard with the soft palate. Dermoid elements were never detected.

Origin of the Pearls.—The question to be decided is, Are the pearls really *inclusion products* ("sequestration dermoids")? The following method was adopted to settle this.

(a) Upper Jaw.—As a rule, new-born full-term children, or fœtuses from 5 and 6 months, were taken, and with care the hard palate, with the alveolar processes and gums, separated by cutting through the floor of the nose. The piece, after being carefully hardened in absolute alcohol, was decalcified in 25 per cent. acidum nitricum, and then embedded in celloidin and cut in series, the sections being either coronal or sagittal. In this manner the palates of 30 fœtuses from 5 to 9 months were examined, and also of 4 fœtuses between 3 and 4 months old. The sections were of course examined in their numerical order.

(b) The lower jaw was examined in the same manner, but only 3 specimens were used.

(c) Eight penes were cut up, having previously been embedded in celloidin. The same applies to the external female genital organs, of which 3 specimens were used. It is obviously of great importance to prepare and examine sections in their numerical order, with a view to tracing the pearls accurately, and in order to see whether they are embedded in the stroma of the corium, or continuous with the surface, *i.e.*, whether they are "inclusion or retention products." The conclusion arrived at is that the pearls are retention products, and cannot be used as evidence in favour of Cohnheim's inclusion theory, or Bland Sutton's assumption of sequestration dermoids.

I. ARGUMENTS AGAINST THE PEARLS BEING INCLUSION PRODUCTS.

(a) Upper Jaw—

- (1) Occasionally pearls are found some distance from the middle line, and these cannot be due to a process of inclusion during the fusion of two epithelial surfaces approaching one another.
- (2) In almost all cases, by examining a numerical series of sections, the pearls could be followed to the surface. Fig. 3 shows the connection with the surface exceedingly well. In this instance sagittal sections were made, and the pearl, which at first appeared to be embedded in the depth of the tissue, could be traced as a duct-like process communicating with the surface epithelium.
- (3) Where this connection with the surface could not be made out, this was due to accidents in cutting the sections, or the pearls were found to owe their origin to glandular lesions.
- (4) The number of pearls varies inversely with the age of the foetus. In a young specimen, even long after the palatine processes have become fused, extremely few are found. This fact argues strongly against the "inclusion theory."
- (5) Pearls were never observed in the substance of the osseous tissue of the hard palate, nor has any other observer ever described their occurrence there. If they were due to inclusion, they should certainly, occasionally at least, be found there.
- (6) The pearls of the dental groove or enamel germ could always be traced to the surface. An exception to this rule did not exist (*v.* fig. 1).
- (7) The pearls on the anterior surface of the gums, as well as those mentioned under (6), cannot in any possible manner be explained as inclusion products. Moreover, they were always traced to the surface.

(8) I have never found the naso-palatine duct as an epithelial tract in any foetus examined, and therefore hesitate to regard the pearls found in the neighbourhood of the papilla incisiva as being due to a blocking up and subsequent inclusion of these ducts (*v. infra*).

(b) *Tonsil*.—The pearls which are constantly noticed here cannot possibly be due to an inclusion, as no fusion of epithelial surfaces takes place here.

(c) *Penis*.—As was remarked above, pearls were never found on the lower surface near the raphé, but always between the prepuce and the glans, and were always easily traced to the surface. The same applies to the *Clitoris*.

II. THE PEARLS ARE EITHER RETENTION PRODUCTS OR DUE TO GLANDULAR DISEASE.

(a) This is easily understood with regard to the *tonsils*. During their development crypt-like processes dip into the adenoid substance. The surface epithelium is continually being shed, and as the crypts are very tortuous, is easily retained in places and compressed, and in a favourable section would give the appearance of a pearl.

(b) In the *upper jaw* several modes of formation of pearls must be considered.

(1) They may be due to glandular disease. This has been maintained with regard to the pearls found in the posterior part of the hard palate by Reubold (6) and Virchow (7). The latter compares them to atheromatous cysts. There can be no doubt that, contrary to Epstein's statements, these pearls are often due to glandular degeneration, as a glance at figs. 4 and 5 will prove. Besides, we often find that the pearls situated here are arranged just like glands, and correspond to them exactly in position. Finally, these pearls (at the junction of the hard with the soft palate) are never found in the foetus before the glands are fully developed. I do not

pretend to offer any explanation why these glandular changes should occur so much more often posteriorly and about the middle line; it may, however, be mentioned, that in the foetus and new-born child the glands do not reach far forwards, nor do they extend much laterally.

- (2) In a second set of cases the pearls are formed in a manner identical with that in which the occasional pearls found in normal skin or in pachydermatous processes are developed.
- (3) In other instances the pearls are due to the retention and subsequent moulding of shed epithelium. During the growth of the palate, crypt-like processes and folds are formed; and in the lacunæ thus established, the epithelium is retained. A glance at the hard palate of any new-born child shows how very uneven the surface is; a great number of transverse ridges are seen, and these ridges are folded back on the surface, so that on a sagittal section we find a number of crypts in which epithelium may be retained. If these should be favourably cut, the appearance of a pearl is easily obtained.

For a long time I found great difficulty in explaining the large pearls constantly found at each side of the papilla incisiva (*v.* fig. 1). They can hardly be due to a blocking of the naso-palatine duct, for the latter, as an epithelial duct, was not once found in a large number of cases examined. But on each side of the prominent papilla a deep narrow fold exists, and in successful sections the whole of this fold may be hit off (*v.* figs. 3 and 6). It is obvious that in a less fortunate section, or with an incomplete series, we would have the appearance of a pearl embedded in the depth of the tissues.

(*c*) No more need be said with regard to the pearls found in the *penis* and *clitoris*. They are undoubtedly due either to the moulding of shed epithelium retained between the prepuce and the glans, or to an increased proliferation of the epithelium, corresponding exactly to the pearls found in normal or pachydermatous skin.

Conclusion.—The conclusion arrived at therefore is, that the pearls found in these situations are not inclusion products, but due either to a retention and subsequent moulding of the shed epithelium within crypts and folds which in all cases communicate with the surface, or to glandular changes, or that they are developed in the same manner as the pearls of normal or pachydermatous epidermis. They cannot therefore be considered in the light of "sequestration dermoids," or "included embryonic germs."

LITERATURE.

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 - (3) H. LÉBOUCQ, *Arch. de Biologie*, 1881, ii. p. 400.
 - (4) A. A. KANTHACK, *Illustrated Med. News*, 1889, vol. ii.
 - (5) SCHWEIGGER-SEYDL, *Virchow's Archiv*, lvii. pp. 220, 227.
 - (6) REUBOLD, *Virchow's Archiv*, vii. pp. 85, 91.
 - (7) VIRCHOW, *Virchow's Archiv*, viii. p. 384; and *Pathologie*, ii. p. 286.
- Also BOHN, *Mundkrankheiten der Kinder*, 1866, p. 52.
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EXPLANATION OF PLATE XI.

The drawings (figs. 4 and 5) were executed by R. Schwann, Esq., of Berlin. The photographs were prepared by my brother R. Kanthack, from unstained specimens, with Zeiss's microphotographic apparatus, apochromatic lenses being used in each case. It is with great pleasure that I here express my gratitude for his help and assistance.

Fig. 1. Coronal section through the hard palate and floor of the nose of a full-term child: *a*, lower part of septum nasi; *b*, lower end of inferior turbinated bone; *c*, papilla incisiva (epithelium torn from the underlying mucosa); *e*, fold or crypt between the papilla and the palate; *f f'*, the two dental grooves converging towards *d*. These are made up of a string of pearls continuous with the surface.

The three pearls between *d* and *e* were in subsequent sections traced to the surface, the two lateral ones ending at the angles of *e*.

Fig. 2. A typical epithelial pearl (Zeiss D).

Fig. 3. Sagittal section through the papilla incisiva: *a*, surface

epithelium; *c*, papilla incisiva. This section shows splendidly the formation of pearls in this locality. In a coronal section the duct-like process would appear as a pearl embedded in the depth.

Figs. 4 and 5. Two consecutive sagittal sections through the palate at the junction of the soft with the hard palate, to show the glandular origin of pearls: *a*, surface epithelium; *b*, bone of hard palate. The glands are seen to disappear in the pearls.

Fig. 6. Sagittal section through the anterior half of the hard palate showing the fold on one side of the papilla incisiva in section: *a*, surface epithelium; *b*, dental groove; *c*, papilla incisiva; *e*, fold on one side of the papilla in section. A tall epithelial process is seen to rise from the surface of the gum at *d*. It is obvious that in coronal sections the crypt of *e* would appear as an included pearl.

Fig. 7. Section through the hard palate of a newly-born child: *a*, bone; *b*, corium of mucous membrane and periosteum; *c*, epithelium.

Fig. 1.



Fig. 3.



Fig. 4.



ADENOMA OF THE BREAST IN CHILDHOOD. By
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(PLATE XII.)

THE occurrence of adenoma—or “glandular tumour”—of the breast below the age of puberty is one of such rarity, if, indeed, it is not unique in pathological record, that no apology is needed for describing in some detail two cases which have recently come under my observation.

The first occurred in the practice of my colleague, Mr M'Ardle, and to his kindness I am indebted for the opportunity of examining it and determining its histological character. The girl, who was just 13 years of age, was sent up to St Vincent's Hospital from the south of Ireland last October, supposed to be suffering from chronic abscess in the left breast. In the absence of Mr M'Ardle she first came under my notice, and it was at once evident that we had to deal with a solid growth and not with an abscess. There was a history of a fall and injury to the breast about a year previously, and to this the growth was supposed to be due; at any rate, it was first noticed one or two months after the accident. It had gone on slowly increasing in size, absolutely without pain, tenderness, or any other symptom. The child's general health was excellent, and she looked well and was well nourished. There was no history of a tubercular tendency obtainable. There was commencing development of the normal gland, which was freely movable over the growth. The tumour was about the size of an almond, irregularly oval in shape, and indistinctly lobulated in outline; it was freely movable over the underlying tissues, quite painless to pressure and gave a sense of elasticity, though not of fluctuation, to the touch. Considerable doubt was expressed as to its nature. The age of the patient precluded, it was thought, an adenomatous growth; and it was regarded as most probably of a sarcomatous or of a chronic inflammatory nature. It was removed by Mr M'Ardle, who kindly put it at my disposal

for examination. As it was immediately placed in strong alcohol, no opportunity was afforded me of observing its naked-eye characters.

In the hardened condition it measured 28 mm. in length, 17 mm. in width, and 9 mm. in depth—all outside measurements. It cut somewhat toughly with a firm and uniformly white surface. On examining sections under the microscope, it was found that the greater portion of the growth consisted of a dense fibrous tissue arranged in wavy parallel bundles, and for the main part but sparsely cellular in type. Scattered through this fibrous stroma were numerous groups of glandular acini, some small and round, others large and irregular in shape, which for the most part showed a distinct lumen, and were everywhere sharply defined from the surrounding fibrous stroma by a well-marked basement membrane. They were lined with a simple, or in places compound, columnar or cubical epithelium. Many of the acini had undergone a certain amount of distension, or of "cystic degeneration," and in these many papillary ingrowths projected into the lumen of the tube, giving rise to a sinuous and irregular outline. Many, again, had the lumen obliterated by the actively proliferating and degenerating epithelium, which had here lost its columnar character, except in those cells immediately adjoining the basement membrane. The varying appearances are well seen in the section from which fig. 1, Pl. xii., was drawn. It will be observed in this, that in the immediate neighbourhood of the acini the fibrous tissue is more cellular and less wavy in type.

The second case was that of a child aged 12 years and 9 months, who was brought to St Vincent's out-patient department towards the end of January. She was suffering from a lump in the right breast, and gave the following history:—Three months previously the mother noticed a small "kernel," which was painless, and after a little time apparently went away. About a month later it was again noticed, this time giving rise to pain, and it was also found to be gradually getting larger, until at the end of nearly two months it had attained the size, and very much the shape, of a small fig. There was no trace of mammary development. The growth was seated right below the nipple, which apparently was freely movable over it, as likewise

was the growth over the underlying tissues. It was slightly irregular in outline, giving the sensation of lobulation, and was very tender and sensitive on handling—even the rubbing of the clothes causing pain. It was not continuously painful, but the pain came in darts, and was said to be worse at night, though this statement was afterwards varied. Otherwise the child's health was good, and except for this painfulness, which exactly resembled the so-called "neuralgia of the breast," so often associated with these tumours in young and nervous women, she suffered no inconvenience. However, on account of this, and as the growth was increasing, I recommended its removal, regarding it from the experience gained in the previous case, and the exact identity of the clinical features (except the pain), as another example of adenomatous growth. Accordingly, on the 28th January, I removed the tumour by a small semilunar incision about half an inch below the margin of the areola. The tumour was definitely encapsuled and was freely detachable underneath, but in front and above the capsule was adherent to the skin, so that at the upper limit, about an inch above the nipple, a small elliptical piece of skin had to be removed in order to ensure the complete removal of the growth. The wound united throughout by first intention, and the child was going about at the end of a week.

On making a section of the fresh tumour, which measured 35 mm. in length, 27 mm. in breadth, and 13 mm. in depth—all extreme measurements—the cut surface presented a peculiar, pearly-white, in parts almost translucent, appearance, as if composed of a collection of half-boiled grains of sago—in each a dull opaque whitish centre, with a clear greyish translucent halo round it. It was quite soft on cutting into it, and exuded a clear mucinoid juice. On examining sections under the microscope, it was found to resemble very closely in its general features the growth described above. The fibrous inter-acinous stroma was, however, finer and more delicate in texture, and was composed of slender interlacing bundles of connective tissue, between which lay long flattened nuclei. These were few in number, except in the neighbourhood of the acini, where in many parts a distinct small-celled infiltration had occurred. The general features are well shown in fig. 2. Under a higher power it was

seen that in many of the larger acini, active cell-proliferation was going on, taking in many cases the form of epithelial ingrowths. These, it could be seen, consisted at first merely of a heaping up and protrusion into the lumen of the growing lining epithelium, which at the same time lost, except near the basement membrane, its columnar type. In a more advanced stage it was seen that a fine core of delicate connective tissue was now projected into the mass of proliferating cells, thus forming a distinct papillary ingrowth, so that the lumen of some of these distended acini was almost obliterated by the intra-acinous growths. These stages of formation are illustrated in fig. 3. The drawing also shows in the neighbourhood of the acini the more cellular type of the stroma and the small-celled infiltration which surrounded many of them. These cells were embryonic in type, and were either proliferating tissue cells or an exudation from the blood-vessels. I incline to the former view, although in some places they seemed to bear a definite relation to the vessels, as in fig. 3; but in no place were they sufficiently numerous to justify the view that any sarcomatous development was in process. Further, in no place could the evident epithelial proliferation be found to transgress the limits of the basement membrane, it was always intra-acinous, so that in no part did the growth show the characters of an infiltrating, or "destructive" (*destruivendes*) adenoma.

Based on their microscopic characters therefore, from the relative amount of fibrous stroma and glandular tissue, these tumours must be classed as fibro-adenomata. They differ from the *true* or simple adenoma met with in the breast and represented in fig. 4, by the relatively greater proportion of fibrous to glandular tissue, and also by the character of the inter-acinous stroma. This in the true adenoma is an excessively delicate tissue composed of a network of branching, stellate cells, and of cells with oval, vesicular nuclei lying between these fine fibres. In this pure form, adenoma is one of the rarest of breast tumours, the majority of cases conforming to a fibro-adenomatous type.¹ The two growths which are recorded above are interesting again

¹ The tumour represented in fig. 5 was removed from the breast of a young unmarried girl. It is the only example of pure adenoma of the breast I have met with.

as presenting an intermediate stage between the simple adenoma and the proliferating cystic adenoma which occurs in the breast, but is more commonly met with in the ovary. I have given a drawing of this condition for comparison in fig. 5. It was removed from the breast of a woman aged 50. Here with marked dilatation of the acini and secondary disappearance of the intervening stroma, we have well-marked papillary intra-cystic growths, such as are so frequent in the cystadenoma papilliferum of the ovary. But the sequence shown in these drawings proves most conclusively the identity of the process, and is most instructive in the light it throws on the successive stages. As long as the epithelial proliferation remains *intra-cystic*, we have the comparatively benign proliferating cystic adenoma; but, if the epithelial development becomes *extra-cystic*, and crossing the basement membrane runs riot in the inter-acinous stroma, then we have, on the other hand, the infiltrating adenoma, or early stage of the adeno-carcinoma, with its rapid local malignancy and distant metastatic deposits.

The rarity of such adenomatous tumours even in early adult life is well recognised. Gross analyses 23 examples of these growths: only 4 occurred between the tenth and the twentieth year; 6 between the twentieth and thirtieth, a proportion which holds almost constant up to the fiftieth year, after which age only two cases are included. "Of the entire number not a single one occurred before the sixteenth year, or during the developmental state of the mamma; 16, or 69·5 per cent., appeared previous to the fortieth year, or during the period of the greatest functional activity of the breast."¹ Of 55 cases observed by Velpeau, only 8 occurred between the ages of 15 and 20, and not a single one before the fifteenth year; and of 130 other cases collected by him, 35 occurred between the ages of 15 and 30, but, again, none earlier than the fifteenth year.² "These '*adeno-fibromata*,'" writes Mr Bryant, "are found, as a rule, in the young and unmarried, and in the apparently healthy and robust. . . . In women the majority of these

¹ Gross, art. "Tumours of the Breast," *Amer. Syst. of Gynecol. and Obstet.*, vol. ii. p. 266, Edinburgh, 1888.

² *Nouv. Dict. de Méd. et de Chir. Prat.*, tome xxi., art. "Mamelles," Paris, 1875.

cases begin to grow, or are first discovered, between the ages of 21 and 30, although, as shown by my table, almost as many begin in younger people, at or after puberty; at later periods of life they less frequently originate, although they may be frequently found to exist in them.”¹ Mr Bryant gives the results of “100 cases consecutively observed, seen, and analysed,” and of these “27 cases were first discovered between puberty and the age of 20, that is, during the developmental stage of the breast’s life;” but not one of these cases occurred under puberty, and no mention is made of any such case being on record. Indeed, it would appear from the literature of the subject that *a growth of any kind in the breast before its period of development or of functional activity has been hitherto undescribed*. Sir James Paget writing of “mammary glandular tumours” and their rate of growth, says:—“One was removed from a woman twenty-seven years old; it was observed for fourteen years, and in all that time it scarcely enlarged; yet after this it grew so rapidly, that in six months it was thought imprudent to delay the removal.”² This, if the dates are reliable, would place its development from the fourteenth year, and is the earliest example I can find recorded.

One point of peculiar interest in my second case is the entire absence of any trace of glandular development on the healthy side. But that an adenoma should occur before the secreting tissue of the breast has shown signs of development is, however, no more remarkable than that such a growth should form after the gland has ceased to be functionally active, and has under natural conditions undergone fibrous atrophy. Yet Velpeau records a case occurring in a woman aged 85! The occurrence of these tumours at the extremes of life must therefore, I think, be explained by a common theory; and to such a theory a leading pathologist has already given expression. Writing of the occurrence of adenomata in general, and the absence of any special age liability—in so far as such growths have been observed to occur congenitally or in the earliest years of life as well as in extreme old age—Birch-Hirschfeld remarks:—“It is, however, probable that those glandular tumours which

¹ *Diseases of the Breast*, p. 102, London, 1887.

² *Lectures on Surg. Pathology*, 4th ed., p. 580, London, 1876.

first become apparent in later life are in reality the outcome of embryonic rudiments.”¹ Whatever light the future may throw on the origin of heteroblastic growths at all periods of life, we must be content for the present to let the question lie enveloped in the same darkness that surrounds many other problems of the pathology of to-day, if we decline to accept the only alternative—the theory of “embryonic rudiments.”

¹ Eulenburg's *Real-Encyclopädie der gesam. Heilkunde*, vol. i., art. “Adenom.”

THE SECTIONAL ANATOMY OF AN ANENCEPHALIC
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THE external appearances of the anencephalic foetus are such as to suggest a disturbance of the relations of the internal organs to each other and to the vertebral column, and it was with a view to the demonstration of what these changed relations were that I examined one specimen of anencephaly by the frozen sectional method. The foetus chosen for the purpose of this investigation was one sent to Prof. A. R. Simpson by Dr Miller of Sunderland, and I have to thank Dr Simpson for permission to examine it.

The *Clinical History* of the case may be given in Dr Miller's own words :—"In April 1888, the mother gave birth to an anencephalic foetus. There was large excess of the liquor amnii, and the labour was very tedious. The mother on this occasion attributed the deformity to a fright received whilst carrying the child. She states that she has a great horror of frogs, and that whilst walking in the country a friend took up a dead frog and threw it at her. On her telling this to the nurse, she confirmed her in her opinion by saying that the child had the appearance of a frog. Six weeks after the birth of this child she menstruated slightly; she then became pregnant again, and expected the child about the beginning of March 1889. However, on January 27th, I was called to see her, and found her in labour, the os uteri being about the size of a half-crown piece. I waited till the os was largely dilated, and then ruptured the membranes, after which there was a tremendous gush of waters. Two or three pains now served to expel the child which proved to be anencephalic like the former one." Her husband, whose second wife she was, had had by his first wife a child that died of hydrocephalus, and another that succumbed to spinal disease.

The interesting facts about the clinical history were (1) that the mother gave birth to two anencephalic foetuses in succession; (2) that there was hydramnios in both cases; and (3) that the husband had had by a previous wife two children, one of whom died of hydrocephalus and the other of spinal disease. This last-named fact is no doubt of far greater etiological value than the alleged maternal impression, for it would seem to show that the father in this particular instance had a tendency to procreate infants with a

morbid cerebro-spinal system ; and the history of the birth of a child with hydrocephalus assumes some importance when it is borne in mind that anencephaly is by many considered as due to an early foetal hydrocephalic condition.

The anencephalic eight months' foetus, which was a female, was placed in the freezing mixture in the dorsal posture, with the thighs partially flexed on the abdomen and the arms lying by the sides. When frozen, a vertical mesial section of the head and trunk was made, a transverse one of the right half of the trunk at the level of the second lumbar vertebra, and several sections of the joints and of the feet. The appearances seen on section were traced and then drawn, and from their study, and from such further dissection as was required, the anatomical peculiarities of this foetus were arrived at.

External Appearances.—The foetus, a female, measured 38 cm. from head to heel, and the trunk alone was 23 cm. in length. The head measured in what may be called the diameter occipito-frontalis 5·5 cm., and in the diameter occipito-mentalis 6·8 cm. The transverse diameter both in front of and behind the ears was 6 cm. The transverse measurement of the face between the malar bones was 5·5 cm., and the vertical or fronto-mental was 6 cm. The transverse diameter of the shoulders measured very nearly 4 cm. The shortness of the foetus and of its head diameters was, of course, due to the peculiar malformation of the cranium.

The monstrous appearance was caused by the absence of the cranial vault and brain and by the existence of a well-marked spina bifida in the cervical region. The head seemed to spring directly from the shoulders, giving to the foetus a neckless appearance ; the face was broad, in comparison with the head ; the mouth was slightly open, and the nose was broad ; the eyes were prominent, half open, and the eyelids were thick and œdematous-looking ; and the ears had a twisted and deformed appearance, and rested on the shoulders, lying in the same transverse plane as the eyes. The vault of the cranium was entirely absent and the basis cranii, covered by a reddish mass of fibres and blood clot, was exposed to view. A large space was thus left on the top of the head, which was continuous with the spina bifida in the cervical region, and was surrounded at its margin by the skin, which carried a few scattered hairs. The forehead could not be said to exist, for the eyes and root of the nose formed the upper limit of the anterior part of the head.

The shoulders appeared relatively broad in comparison with the small deformed head. The rest of the body was well formed, and, as is common in this variety of malformation, there was a relatively large amount of subcutaneous fat. The skin surface had a bright pink colour. The insertion of the stump of the umbilical cord into the anterior abdominal wall was situated 4 cm. above the symphysis pubis and 6 cm. below the tip of the

FIG. 1.—Vertical Mesial Section of Head and Trunk of Anencephalic Fetus, left face shown ($\frac{1}{2}$ nat. size). A, bones fused together forming basis cranii; B, spina bifida; C, 7th cervical vertebra; D, hyoid bone; E, cricoid; F, thyroid gland; G, thymus; H, heart; I, liver; K, lobus Spiegelii; L, pylorus; M, transverse colon; N, third part of duodenum; O, second lumbar vertebra; P, oesophagus; Q, aorta; R, right pulmonary artery; S, trachea.

ensiform cartilage. No examination of the placenta, membranes, or cord was possible, as these structures had unfortunately been destroyed at the time of birth.

From the external appearances it was evident that the specimen was one of anencephaly, and that it was of the derencephalic variety of Saint-Hilaire; for, whilst there was both absence of the cranial vault and spina bifida, the latter condition affected only the cervical region.

Regional Anatomy.—From a study of the frozen sections and from some further dissection, it was possible to investigate the regional anatomy of this foetus. Unfortunately, the vertical mesial section had not followed exactly the middle line of the body; it had deviated slightly to the right in the region of the face and to the left in the lower dorsal, lumbar, and sacrococcygeal regions. This must be borne in mind in referring to the accompanying illustrations (figs. 1 and 2).

The Region of the Head.—In this region were found the most marked abnormalities. As may be seen from the sagittal section, there was a complete absence of cerebrum and cerebellum along with the bones which normally roof in the cranial cavity. In the middle line could be seen the base of the cranium, lying almost entirely in the same plane, composed partly of bone and partly, but to a small extent only, of cartilage, and showing an irregular arrangement of parts. Posteriorly, there was no trace of the foramen magnum; what appears to be the basi-occiput terminated abruptly, and was in immediate contact inferiorly with the altered odontoid process. Anteriorly, the basi-occiput appeared to be fused with the body of the sphenoid, which did not show any indication of the plate of cartilage which normally exists between the basi- and pre-sphenoid (fig. 1, A). The sphenoid had lying in front of it the cartilaginous ethmoid. On the altered basis cranii lay a mass of blood clot, rendered spongy by numerous fibres which traverse it, and covered by a membrane which was continuous with that closing in the cervical spina bifida, and which was firmly attached to the margins of the bones which formed the boundaries of the area on the upper surface of the head. In the region of the face, as seen in the section, the tongue was seen lying in close contact with the roof of the mouth, dental germs were present in the upper and lower jaw, and the buccal cavity became continuous with the pharyngeal at the level of the fifth cervical vertebra.

The further dissection of the head revealed the following

facts :—The nasal spine and posterior part of the orbital plate of the frontal were the parts of that bone which were present. It articulated with the nasal bone, with the lachrymal, with the ethmoid, and with the pre-sphenoid and its great wing on that side. The external angular process of the frontal articulated with the zygomatic process of the temporal. The nasal bones were abnormally large and well ossified. The malar bones were also large, and each articulated with the external angular process of the frontal and with the great wing of the sphenoid, but not directly with the zygoma of the temporal bone. The petrous, mastoid, and zygomatic parts of the temporal were present, but the squamous part and the annulus tympanicus were entirely wanting. The zygoma articulated, as has been said, with what may be looked upon as the external angular process of the frontal. The inner end of the petrous part was fused with the sphenoid, and thus, together with the basi-occiput, formed a large keystone in the centre of the base of the cranium. There was no condyle on the petrous part of the temporal for articulation with the lower jaw. In its place was found a small spine, which projected between the coronoid process of the lower jaw and a projection representing the neck of that bone below the condyle, for the mandibular condyle was absent. Above and behind the odontoid process of the axis was a small fragment of bone, which might represent a part of the basi- or supra-occiput displaced downwards, or might be the dislocated ring of the atlas. The ex-occipitals articulated with the transverse processes of the atlas, which were long and well ossified. The supra-occiput seemed entirely wanting. The basi-occiput was present, and has been already mentioned. There was no trace of the parietal bones. The great wings of the sphenoid, as well as the pre- and post-sphenoid, were present; but the small wings were either absent or fused with surrounding parts, perhaps with the orbital plate of the frontal; one very crooked pterygoid process was present on each side. The ethmoid was entirely cartilaginous. The superior maxilla contained the dental germs of two incisor, one canine, and three molar teeth. The inferior maxilla was well ossified, and showed a peculiar bony ledge projecting anteriorly below the symphysis menti. The coronoid processes were present, but the condyles were absent. It is evident that the

bones which were wanting in this case were almost exactly those developed in membrane; the bones of the base which are pre-formed in cartilage, and those of the face, were practically all present, although some of them were deformed.

The Vertebral Column (figs. 1 and 2).—All the vertebræ were represented, although the upper cervical were manifestly imperfect. The anterior part of the ring of the atlas may be

Fig. 2. Del.

FIG. 2.—Vertical Mesial Section of Pelvic Region in Anencephalic Fœtus, right face shown (nat. size). A, fifth lumbar vertebra; B, rectum, first part; C, rectum, second part; D, coccyx; E, uterus; F, bladder; G, vagina; H, symphysis pubis; I, clitoris; K, left labium minus; L, right labium.

fused with the odontoid process or with the basi-occiput, whilst the posterior part of the ring may be represented by the fragment of bone lying behind and above the upper end of the spine. The total length of the vertebral column was 21 cm.; the cervical region measured 3·7 cm., the dorsal 8·3 cm., the lumbar 4·5 cm., and the sacro-coccygeal 4·5 cm. in length. With regard to its curves, the spine showed a distinct convexity forwards in the lumbar region, a concavity anteriorly in

the dorsal region and the usual projection of the promontory of the sacrum, and the slightly-marked sacro-coccygeal curve. The dorsal and lumbar curves were probably due to the position in which the body was placed during freezing, but in the cervical region was a state of affairs which could not thus be explained. The cervical part of the spine was curved backwards, so as to develop a marked anterior convexity, and this existed notwithstanding the fact that the chin of the child was in close and permanent contact with the thorax. This fact serves to explain the apparent absence of a neck in this foetus; for the head, instead of being articulated with the apex of the spine, rather rested upon the anterior surface of the first three or four cervical vertebral bodies. The head had, as it were, slipped down in front of the upper part of the spinal column.

Since the above described arrangement of the cervical part of the spine seemed to have such an important bearing upon the relation of parts in the anencephalic foetus, I was anxious to find if it was invariable in this species of monstrosity. So, a few weeks ago, when another specimen of anencephaly came into my hands, I made a vertical mesial section of the head and neck in that case also. In it (fig. 3) a different arrangement of parts was found to exist. The basis cranii (fig. 3, A and B) did not run so nearly horizontally as in the first; at its posterior end it bent sharply downwards, so that the basi-occiput lay posterior to the upper cervical vertebral bodies. The cervical region of the spine was curved with an anterior concavity instead of a convexity, and the posterior part of the base of the cranium rested on the posterior instead of on the anterior surface of the upper part of the spinal column. In the first specimen a considerable interval intervened between the anterior aspect of the cervical spine and the back of the pharynx; in the second there was only a very small space in this position. In both cases, however, the neckless appearance was produced, but the manner of production was different. No doubt, both arrangements exist in anencephalic foetuses, although which is the more common I do not know. Taruffi (*Storia della Teratologia*, tomo vi., p. 104) figures a case in which the anterior concavity in the upper cervical region was even more marked than in the instance above recorded.

To return to my first specimen, the ossification of the spine was found to be normal in all the regions save the cervical, where there was a well-marked spina bifida (fig. 1, B). Here the spines and arches of the four first cervical vertebræ were absent, or rather the spines were absent, and the arches were flattened out so as to pass transversely, leaving a wide open

F

C

H

FIG. 3.—Vertical Mesial Section of Head of second specimen of Anencephalus (nat. size), right face of section shown. A, sphenoid; B, basi-occiput; C, body of axis vertebra; D, hyoid bone; E, thyroid cartilage; F, septum of nose; G, Eustachian tube; H, tongue.

space covered by a membrane continuous with that on the basis cranii, and containing blood clot through which fibrous structures passed up to be inserted into the covering membrane. In the rest of its extent the spinal canal was closed in posteriorly; but it seemed to be unusually large, measuring in the dorsal region 1 cm. antero-posteriorly. The spinal cord was present in a somewhat shrunken form in the dorsal and lumbar regions, but in the cervical only the spinal membranes were seen.

The Region of the Neck.—The reason why the anencephalic fetus appears destitute of a neck, although the cervical part of the spine is of normal length, has already been described. The hyoid bone (fig. 1, D) lay above and slightly in front of the thyroid cartilage of the larynx at the level of the 7th cervical vertebra; it was situated 1.4 cm. in front of the spinal

column, and the space between it and the thyroid cartilage measured only 1 mm. in breadth. (In my second specimen the hyoid bone (fig. 3, D) lay opposite the 3rd cervical body, and nearly 2 cm. in front of the vertebral column.) The upper laryngeal opening covered by the epiglottis lay at the level of the body of the 6th cervical vertebra, and the larynx extended vertically from this point to the lower border of the 1st dorsal vertebra, a distance measuring 1·2 cm. The thyroid cartilage lay opposite to the disc between the 7th cervical and the 1st dorsal vertebra, whilst the posterior part of the ring of the cricoid lay opposite the 1st dorsal body (fig. 1, E). The antero-posterior diameter of the larynx was 6 mm., and the lower margin of the cricoid was situated 8 mm. above the manubrium sterni.

The isthmus of the thyroid gland (fig. 1, F) lay in front of the trachea, at the level of the disc between the 1st and 2nd dorsal vertebræ; it corresponded in vertical extent to the 1st, 2nd, 3rd, 4th, and 5th rings of the trachea. The upper end of the trachea lay opposite to the lower border of the 1st dorsal vertebra. A comparison of the levels occupied by the structure in the neck in this case, and in a normal foetus, reveals an interesting fact; all the parts lie at a lower level *quâ* the spine, in this anencephalic foetus, than they do in a normal case. The hyoid bone, which normally lies opposite one or other of the upper cervical vertebra, differing according to the position of the head, lay in this case at the level of the last cervical body; and, in a similar way, the larynx, the thyroid gland isthmus, and the upper end of the trachea, were all two or three vertebral bodies below their normal positions. The forepart of the head had, as it were, sunk down in front of the cervical part of the spine.

The Region of the Thorax.—The sternum had two ossific centres, one in the manubrium and one in the body of the bone; it measured 4·8 cm. in length, and it was slightly curved with a posterior concavity. The central tendon of the diaphragm lay at the level of the 8th dorsal vertebra. The vertical diameter of the thoracic cavity in the middle line, from the upper border of the manubrium sterni to that of the central tendon of the diaphragm, was 3·4 cm. The antero-posterior

diameter at the level of the 3rd dorsal vertebra was 2 cm.; at the level of the 4th, 2·5 cm.; at that of the 5th, 3·5 cm.; at that of the 6th, 4 cm.; and at that of the 7th, 4·3 cm.

The trachea (fig. 1, S) extended from the level of the lower border of the 1st dorsal vertebra to that of the middle of the body of the 5th dorsal, where it bifurcated; it had a vertical measurement of 4·4 cm., and an antero-posterior diameter of from 1 to 2 mm. The upper border of the manubrium sterni lay opposite to the upper margin of the 3rd dorsal vertebra, and at the level of the 8th tracheal ring. In the sagittal section the heart (fig. 1, H) was divided, the cavities of the right and left auricles being opened into, and the tricuspid valve guarding, the opening into the right ventricle was seen. The valves and apertures of the heart were in the condition in which they are found normally in a foetus of this age. In vertical extent, this organ corresponded to the 5th, 6th, 7th, and 8th dorsal vertebræ, and it was seen to be tilted upwards in front, so that its apex corresponded to the disc between the 7th and 8th dorsal vertebræ. The foramen ovale lay at the level of the body of the 7th dorsal vertebra.

The thymus gland (fig. 1, G), lying in front of the heart and pericardium, extended vertically from the level of the 2nd to that of the lower border of the 5th dorsal vertebra, a distance of 2·3 cm. Its antero-posterior diameter superiorly measured 1·5 cm., and it tapered to a point inferiorly. It had a somewhat triangular shape as seen in section, and at its base it came in contact with the left innominate vein, the trachea, and the thyroid isthmus in the middle line. The lungs were not visible in the mesial section, but dissection revealed them lying at the back of the thorax, unexpanded and small in size. The aorta was seen in the section near its origin from the left ventricle at the level of the 5th dorsal vertebra, and again in the descending part of its course at the level of the 6th, 7th, 8th, and 9th dorsal vertebræ. At the level of the last-named bone it passed through the hiatus aorticus into the abdomen. The ductus arteriosus uniting the pulmonary artery and the aorta was widely patent. The left innominate vein crossed the middle line at the level of the upper border of the 3rd dorsal vertebra.

With regard to the relations of the parts in the region of the

thorax, it was seen that the thymus gland, the trachea, the left innominate vein, and the manubrium sterni were all situated at a lower level than is found in the normal foetus; but the central tendon of the diaphragm lay nearly at the same level with regard to the spine, and the heart in its vertical extent was not far from the normal. The upper limit of the heart corresponded to the 5th and the lower to the 8th dorsal vertebra, and these are its normal relations in still-born foetuses. Now, since the organs in the upper part of the thorax are at a lower level, *quâ* the vertebral column, than is normal, and since the heart is practically in its normal position in this respect, it follows either that the organs were smaller or that the thoracic cavity was larger in an antero-posterior or in a transverse direction (for it was really smaller in the vertical direction, as has been shown). On examination it was found that the organs were not relatively small; and, with regard to the size of the thoracic cavity, it was discovered that, instead of the vertical diameter in the middle line being slightly greater than the antero-posterior (as it is in the normal foetus), it was distinctly less. The conclusion could, therefore, be drawn that room had been found for the thoracic viscera by a bulging forward of the anterior thoracic wall; and, since the transverse diameter of the interior of the thorax was twice the length of the antero-posterior, it is probable that further space for the accommodation of the organs was thus made available.

The Region of the Abdomen.—In the abdominal region the section passed slightly to the left of the middle line, and therefore the parts were not divided exactly mesially. The liver (fig. 1, I), as is always the case in the foetus, was a very prominent organ. In vertical extent it corresponded (in the middle line) to the bodies of the 9th, 10th, 11th, and 12th dorsal, and 1st and 2nd lumbar vertebræ, and it was normal in this respect. The greatest vertical hepatic diameter was 5·2 cm., and the antero-posterior diameter at the level of the 11th dorsal vertebra was 3·4 cm.; both these measurements were made in the middle line of the body. In form the liver was nearly normal, the only peculiarity being that the left lobe was somewhat larger than it usually is in the eight months foetus. The stomach had a somewhat narrow tubular form, and lay

nearly vertically in the abdomen on the left side of the spine, opposite to the 9th, 10th, 11th, and 12th dorsal vertebræ. The duodenum (fig. 1, L) crossed the middle line at the level of the disc between the 1st and 2nd lumbar vertebræ. The umbilical cord was inserted into the anterior abdominal wall at the level of the 5th lumbar vertebra.

The pancreas corresponded in vertical extent with the body of the 1st and the upper half of the body of the 2nd lumbar vertebra. It was at first thought that the spleen was absent in this case, but on dissection it was found packed in alongside of the vertebral column, immediately under cover of the diaphragm; it was very small, measuring only about 2 cm. in length. On account of its small size and its position, it did not possess the same relations to the colon, liver, and stomach as in the normal fœtus. With regard to the small intestine, the duodenum crossed from left to right at the level of the disc between the 1st and 2nd lumbar vertebræ, and its third part (fig. 1, N) recrossed the middle line at the level of the 3rd lumbar body. The coils of the jejunum and ileum were found occupying the abdominal cavity at the level of the 3rd, 4th, and 5th lumbar and 1st sacral vertebræ. The cæcum and ascending colon were not absolutely normal in position; the former lay a little above and internal to its usual site in the left iliac region, and the latter ascended to the neighbourhood of the gall bladder, where it formed a feebly-marked hepatic flexure, and became continuous with the transverse colon. The ascending and the transverse colon were both greatly distended with meconium, and the latter (fig. 1, M) had a somewhat unusual arrangement, due in all probability to the absence of the left kidney and to the large size of the left lobe of the liver. The transverse colon passed to the left along the under surface of the quadrate lobe of the liver, then it turned downwards in the abdomen, formed a loop, and then turned sharply upwards, passing to the under surface of the left hepatic lobe, where it formed the splenic flexure. From this point the descending colon passed downwards as a narrow tube, containing little or no meconium, in close contact with the left side of the vertebral column and firmly attached, to become continuous with the sigmoid flexure. The sigmoid flexure, in marked contrast to

the descending colon, was filled with meconium, and was of large size; it made a marked bend at the level of the 5th lumbar vertebra, and became continuous with the rectum, which was, like it, greatly distended with meconium. The descending colon was, on account of the narrowness of its lumen, in marked contrast with the other parts of the large intestine, which were all over-filled with meconium. There was neither kidney nor supra-renal capsule on the left side of the middle line; but on the right side they were both present, were normal in position, and did not appear to be of greater size than usual.

The bladder (fig. 2, F) was, as is usual in the foetus, almost entirely an abdominal organ. Its cavity had an elongated oval shape, with its long axis running almost vertically. In an antero-posterior direction its cavity measured 1.5 cm., and vertically it had a diameter of 3 cm. It contained a few drops of clear urine.

The Region of the Pelvis (fig. 2).—Lying behind the bladder, and moulded to its posterior wall, was the uterus (fig. 2, E), which lay partly above and partly below the plane of the brim. The vagina (fig. 2, G) passed almost directly downwards, having only a slight inclination forwards at its lower end. The ovaries and tubes were normal. The antero-posterior diameter of the pelvic brim, from sacral promontory to upper border of symphysis pubis, measured 3 cm. The rectum (fig. 2, B and C), distended with meconium, occupied a large portion of the pelvis; it made one bend upon itself opposite to the 3rd sacral vertebra.

The Extremities.—The limbs were well formed. In the lower end of the femur was an ossific nucleus, from 1 to 2 mm. in diameter. There was a large amount of fat in the knee-joint, the infra-patellar pad was of considerable size; there was also a pad between the condyles, and a layer of fat passed backwards upon the head of the tibia. These facts were revealed by a vertical mesial section of the knee. A similar section of the foot showed a centre of ossification in the astragalus, 6 mm. by 4 mm.; and there was also an ossific nucleus in the os calcis, measuring 10 mm. by 8 mm. There was no centre in the cuboid, and that bone was seen to underlie the external cuneiform; and, on further dissection, was found to reach to the inner side

of the middle cuneiform, thus indicating what may be held to point to a certain degree of commencing talipes.

To summarise: the important anatomical details in this specimen were (1) the condition of the bones of the head, the absence of the vault bones, and the deformity of the base bones; (2) the abnormal arrangement of the cervical part of the spine; (3) the displacement downwards, *quâ* the spine, of the soft parts in the region of the neck; and (4) the absence of the left kidney and supra-renal capsule.

The frozen sectional work in connection with the first specimen was carried out in the Laboratory of the Midwifery Department in the University of Edinburgh, that in connection with the second in the Royal College of Physicians' Laboratory.

THE RELATIONS OF THE PERITONEUM TO THE
DESCENDING COLON IN THE HUMAN SUB-
JECT. By JOHNSON SYMINGTON, M.D., F.R.S.E., *Lecturer
on Anatomy, Minto House, Edinburgh.*

(Read before the Anatomical Society, May 23, 1892.)

NOTWITHSTANDING the importance of this subject from a surgical point of view, and also its developmental interest, the fate of the primitive descending meso-colon, and the relative frequency of the existence of a mesentery for the descending colon during the later months of foetal life and after birth, are questions upon which anatomists are by no means agreed.

It is unnecessary for me to attempt an exhaustive resumé of the literature on this subject, as this has already been done by Professor Toldt¹ in a very able and interesting communication. Since Toldt's paper the most important work dealing with this subject is that by Mr Frederick Treves. I refer to his *Hunterian Lectures on the Anatomy of the Intestinal Canal and Peritoneum in Man*, 1885. Mr Herbert W. Allingham, in a recently published work on *Colotomy: Inguinal, Lumbar, and Transverse*, gives the result of some original investigations that he has made on the relations of the peritoneum to the colon, and numerous references to this subject will be found in papers dealing with inguinal *versus* lumbar colotomy.

My own investigations are based mainly upon a study of the relations of the peritoneum to the descending colon during the latter half of foetal life, but they have an important bearing upon its condition during extra-uterine life.

It is generally admitted that the descending colon gradually shifts its position from near the middle line, so that in foetuses from 3 to 6 inches in length it is usually found along the outer border of the left kidney, but attached by its long mesentery to the abdominal wall near the middle line. I show you a

¹ "Bau und Wachstumsveränderungen der Gekröse des menschlichen Darmkanales," *Denkschriften d. k. Akad. der Wissensch.*, Wien., bd. xli., 1879.

horizontal section through the abdomen of a foetus $3\frac{1}{2}$ inches long, in which this condition is well seen (see fig. 1). Two main views have been advanced to account for the subsequent disappearance of the mesentery, or the shifting of its attachment from near the middle line to the outer side of the kidney. Treitz, Luschka, and Hyrtl have attributed its disappearance to the growth of the abdominal wall by which the two layers of the mesentery are separated from one another at their base, and are used up in the formation of the parietal peritoneum, until finally the posterior surface of the colon loses its peritoneal covering. Waldeyer agrees with the above view, but he also thinks that the growth of the kidney is a factor in causing a disappearance of the mesentery. Langer¹ and Toldt² ascribe the fixation of the descending colon to the agglutination of the posterior layer of its mesentery with the parietal peritoneum behind it. The adhesion is at first very loose, and can easily be torn. According to Toldt, this union of the descending meso-colon with the parietal peritoneum begins above near the splenic flexure, and passes from this level downwards. The agglutination occurs readily over the kidney, as the prominence of this organ tends to bring the layers in close contact. Just internal to the kidney, however, there is a longitudinal depression, and here union often does not occur or is delayed for a few months, and hence the formation of the primitive intersigmoid fossa. This recess is funnel-shaped, extends upwards internal to the kidney along the course of the ureter, and opens below behind the mesentery of the sigmoid flexure. It is very commonly found in foetuses of the fifth and sixth months, and as Toldt maintains, its presence affords strong confirmation of his views as to the mode of obliteration of the descending meso-colon. In several foetuses at this age I have found on dissection appearances which seemed to be due to the adhesion of the descending meso-colon with the parietal peritoneum.

I have investigated the relation of the peritoneum to the colon, from the fifth to the ninth month of foetal life, by hardening the entire foetus in spirit or Müller's fluid. The body was injected with the hardening fluid by the umbilical vein as soon as received, and preserved in the same fluid until thoroughly

¹ *Lehrbuch der Anatomie*, Wien., 1865.

² *Op. cit.*

hardened. In some cases the hardening of the abdominal viscera was facilitated by making a transverse cut through the abdominal wall superficial to the liver, so as to allow the fluid to enter the peritoneal cavity. After the trunk was well hardened, a horizontal section was made through the abdomen at or near the level of the umbilicus. Usually two horizontal sections were made, one a little above the umbilicus in front, and passing posteriorly through the kidneys, and another at the level of the umbilicus, dividing the posterior abdominal wall below the kidneys and above the iliac crests. The relations of the peritoneum were then carefully examined in the plane of the section, and subsequently the coils of the small intestine were turned aside to permit of an inspection of the whole length of the descending colon. This plan gives excellent results, and is much less laborious than the freezing method. It appears to me essential, for a satisfactory determination of the relation of the peritoneum to the colon, that some means should be adopted so that the parts are thoroughly hardened before the abdominal viscera are exposed. I have examined, by the above method, six foetuses at the fifth month, four at the sixth, two at the seventh, two at the eighth, and five at full time.

At the fifth and sixth months, the obliteration of the primitive meso-colon and the subsequent fixation of the descending colon is usually completed where the colon lies against the outer part of the kidney. This was the case in eight out of the ten foetuses examined. In one case, a six months foetus, the upper part of the descending colon was placed external to the kidney, but as it passed downwards, the colon gradually inclined inwards in front of the kidney. It had no mesentery at its upper end, but opposite the lower half of the kidney it had a mesentery, which was attached posteriorly to the anterior surface of the kidney. This mesentery became continuous below with that of the sigmoid flexure. In the other case the descending colon had a similar relation to the kidney, but it did not acquire a mesentery until it reached the lower end of the kidney.

In the eight specimens at the fifth and sixth months, in which there was no meso-colon at the level of the kidney, only about half the circumference of the bowel was covered by peritoneum. The surface uncovered rested partly upon the kidney and partly

against the abdominal wall immediately external to the kidney. In six of these eight fetuses there was no mesentery to the colon between the kidney and the iliac crest, but in two of them it acquired a mesentery opposite the lower end of the kidney. Nine specimens were examined between the seventh and ninth months of foetal life, and in none of these was there a descending meso-colon either opposite the kidney or between this organ and the iliac crest, and on an average nearly half of the circumference of the bowel was uncovered by peritoneum. This was the case both in those specimens in which the colon was nearly empty and those in which it was distended with meconium. The colon passed vertically downwards along the outer border of the kidney, and at the lower end of the kidney it turned inwards to reach the outer border of the psoas. Here it again changed its direction, passing downwards in front of the iliac crest to join the sigmoid flexure.

Fig. 2 shows a horizontal section of the abdomen of a nine months male foetus, passing through the lower part of the umbilicus in front, and the upper part of the 5th lumbar vertebra

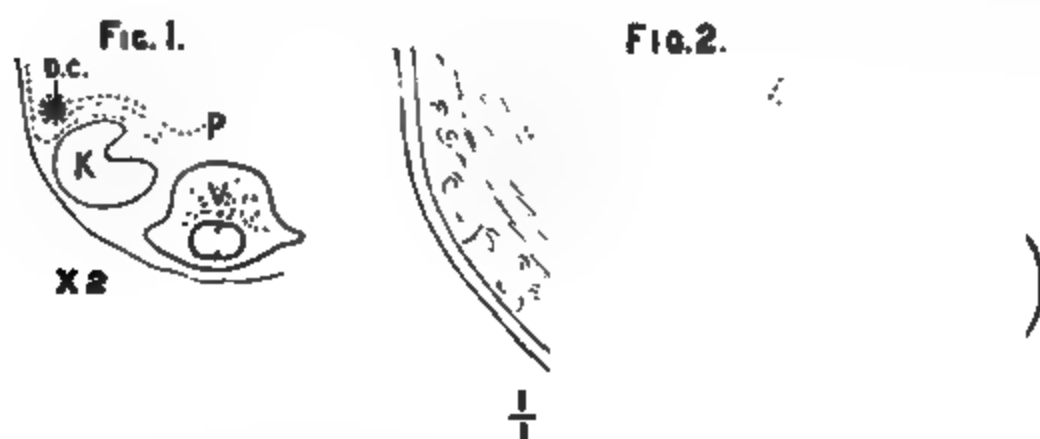


FIG. 1.—Transverse section through abdomen of a foetus $3\frac{1}{2}$ inches long. D.C., descending colon; P., peritoneum; K., kidney; V., vertebra.

FIG. 2.—Transverse section through abdomen of a nine months foetus. D.C., descending colon; Ps., psoas muscle; Q.L., quadratus lumborum; E.S., erector spinae; L.V., lumbar vertebra.

behind. It was immediately above the iliac crests and below both kidneys. Both the descending colon and the sigmoid flexure were distended with meconium. As can be seen from the figure, the inner aspect of the colon lying near the psoas and the posterior aspect placed in front of the quadratus lum-

borum were uncovered by peritoneum, while the anterior and external surfaces were provided with a serous investment.

The part of the circumference of the colon covered was $\frac{7}{8}$ of an inch in extent, while that uncovered was $\frac{1}{8}$ of an inch. In another case, a nine months female foetus, the descending colon was nearly empty and flattened from before backwards. In this specimen not more than half of the circumference of the colon was covered by the peritoneum.

I am well aware that these results do not agree with those of various other observers. Luschka¹ asserts that in the new-born child the vertical portions of the colon are completely surrounded by peritoneum, and movable, and also nearer the middle line. My results, however, agree with those of Toldt, and I believe they represent the normal relation of parts. These conclusions have an important bearing upon the question of the relation of the peritoneum to the descending colon during extra-uterine life. Thus Mr Frederick Treves² writes—"From the standpoint of development and comparative anatomy, it would certainly be expected that a descending meso-colon would be much more frequently met with than an ascending meso-colon. . . . It is the remains of the primary vertical fold of peritoneum, whereas the ascending colon is a secondary production, a fold required by a certain phase in the development of the bowel" (p. 55). From the above quotation it is evident that Mr Treves regards the descending meso-colon of the adult as resulting from the persistence of the primitive mesentery. If, however, the descending meso-colon of the young foetus be normally obliterated by the end of foetal life, it is obvious that the mesentery described by various authorities as of frequent occurrence in the adult must be a secondary formation, and not, except in rare cases, the remains of the primitive descending meso-colon.

I have not yet met with a mesentery for the descending colon, either in the child or the adult, in subjects examined after freezing the abdomen and making horizontal sections of the body in the region of the descending colon. My cases, six children and two adults, are, however, too limited in number to justify any definite opinion as to its relative frequency. In one

¹ *Die Anatomie*, bd. ii. p. 172.

² *Op. cit.*

case, a boy aged 5 years,¹ the descending colon did not occupy its normal position, but passed downwards internal to the left kidney. In this case there was no mesentery. I have notes of several cases of a similar kind in adults, and in these also there was no mesentery. In the other five children the bowel was normal in position. Pl. xi. fig. 1 of my work on the Anatomy of the Child represents a horizontal section of the abdomen of a girl six years old, made between the last rib and the iliac crest. In this case the bowel was empty and contracted, and just about one-half of the part of the descending colon divided in the section was uncovered by peritoneum.

I am of opinion that the frequency of occurrence of a descending meso-colon has been greatly exaggerated, and the methods adopted for the investigation of the peritoneal relations of the descending colon have been unsatisfactory, and in some cases have tended to develop a mesentery where it did not normally exist.

Professor P. Lesshaft² described a descending meso-colon as existing, on an average, in 1 out of every 6 bodies. Between the ages of 30 and 40 it was 1 in every 4, and between 40 and 50 it rose to 1 in 3.

Mr Frederick Treves³ found a descending meso-colon, varying in length from 1 to 3 inches, in 36 out of 100 bodies he examined. He gives no particulars as to the condition of the bowel, whether empty or distended, or the vertical extent of the mesentery.

Mr Herbert W. Allingham⁴ found a mesentery much more frequently than either Lesshaft or Treves. It may, perhaps, be as well to quote his own words. On page 153 of his work on *Colotomy* he writes:—

“In condition 2, as represented in fig. 30, the colon is entirely surrounded by firmly adherent peritoneum, and has a comparatively short mesentery, so that it is impossible to reach it, or to see the longitudinal bands, without first opening the peritoneal cavity. In this condition the ascending and descend-

¹ See fig. 8, p. 30 of my work on *The Topographical Anatomy of the Child*, 1887.

² “Die Lumbalgegend in anatomisch-chirurgischer Hinsicht,” *Reichert und Du Bois Reymond's Arch.*, 1870.

³ *Op. cit.*, p. 1.

⁴ *Op. cit.*, p. 2.

ing colons have a mesentery of varying length. My own observations show 49 out of 60 cases on the right side and 50 out of 60 on the left side, the percentage therefore being $81\frac{2}{3}$ out of 100 cases on the right side, and $83\frac{1}{3}$ out of 100 on the left side." Mr Allingham does not give any particulars as to the method he adopted in his examination, but if his facts be correct, I presume they must constitute a very serious objection to the operation of lumbar colotomy,—at any rate, as usually performed. Indeed it is difficult to realise how surgeons could have continued for so many years to perform lumbar colotomy and expect to open the descending colon without wounding the peritoneum, when, according to Allingham, this is impossible in 5 out of 6 subjects. Both Treves and Allingham made their observations upon fresh bodies, but they give no particulars as to what precautions they adopted to fix the colon and peritoneum in their normal position.

In many subjects the parietal peritoneum is very loosely attached to the abdominal wall in the lumbar region, especially where it is reflected on to the colon. This looseness of connection is what one would expect from the variations in the

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FIG. 3.—Transverse section through the abdomen of a male adult.
Lettering as in Fig. 2.

quantity of material occupying the colon at different times. It therefore follows that the colon, upon slight traction, can easily be drawn forwards from the posterior abdominal wall and a fold of peritoneum formed behind it, simulating a mesentery. It

must further be noted that the reflection of the anterior abdominal wall and the consequent division of the parietal peritoneum facilitates the formation of this fold.

Fig. 3 represents a horizontal section of the abdomen of a thin male subject, aged 57 years, half an inch above the iliac crest. The colon was empty. In a section through this body an inch higher up, which divided the lower end of the kidney, only half the circumference of the bowel was covered by peritoneum, but here fully $\frac{3}{4}$ was covered. The extent of surface uncovered was only $\frac{1}{8}$ of an inch. In this case the peritoneum covered the anterior and lateral aspects of the descending colon, and also extended round its outer border so as to cover part of the posterior surface. The peritoneum, however, was very loosely attached to the colon where it covered it posteriorly, and I have no doubt that had the bowel been distended, a much larger surface would have been uncovered by the peritoneum. It is specimens such as this which are very liable, in an ordinary post-mortem examination, to be regarded as examples of a descending colon with a mesentery.

A RACIAL VARIATION IN THE LENGTH OF THE PALATE PROCESS OF THE MAXILLA. By A. EICHHOLZ, B.A., *Scholar of Emmanuel College, Cambridge, Assistant Demonstrator of Anatomy, Cambridge University.*

(Communicated to the Anatomical Society, May 23, 1892.)

Method.—Two sets of measurements were taken:—

- A. The length (in the median line of the palate) from the posterior extremity of the maxillary palate process to the summit of the eminence between the median incisor teeth. For each race examined an average of the individual measurements was taken, and a value [L] for each race thus obtained.
- B. The internal width behind the last molar teeth. Here, again, an average race value [W] was calculated.

The specimens examined were those of the Cambridge University and Hunterian Collections.

Results:—

1. The measurements A show a race variation inasmuch as the length [L] in the so-called "higher" races is shorter than the length in the "lower" races. (See Table I. and Table III., column 2.)
2. On arranging the races according to their geographical distribution, it is found that a group of "higher" races occupies as a whole a higher place on the list with respect to [L] than a group of "lower" races, so that the racial variation is gradational from the "higher" to the "lower" races. (See Table II.)
3. The measurements B indicate that [W] shows no racial variation. The variations which do occur may rather be regarded as minor fluctuations of a common mean value. (See Table III., columns 3 and 4.)
4. In consequence of 1 and 3, the difference [L] – [W] should be greater in the "lower" than in the "higher" races. This on the whole is found to be the case, the difference varying from a negative value in the upper races to a comparatively large positive value in the lower races, the transition being gradational.

5. In many individual cases there is an actual or approximate numerical equality of the length of the maxillary palate process and the internal width. Calling all cases equal in which the difference does not exceed 2 millimetres, it is found that the percentages of cases of equality are greater in the higher than in the lower races (see Table IV.), and that the lowering of percentage is gradational. (See Table V.)
6. In correlation with the above-mentioned results stands the fact, that the higher the race the less steep is the typical palate curve in that race.

I take this opportunity of acknowledging Professor Macalister's kind advice and assistance to myself whilst undertaking this inquiry.

TABLE I.—*To Illustrate Result 1.*

Note.—The numbers affixed to the names of the various races indicate the number of measurements from which in each case [L] was averaged. See also Table III., column 6.

[L] Lengths in $\frac{mm}{10}$.		[L] Lengths in $\frac{mm}{10}$.	
354	Irish, 16	404	Japan, 10
360		407	Gulana and Colombia, 10
363	Pre-Celtic British, 41	410	
369	Romano-British, 40	413	Esquimaux, 20; Maori, 20
370		420	Negro, East Coast Africa, 10
373	French, 44	421	Zulu, 10
375	Anglo-Saxon, 29	425	Fiji Islands, 10
380	Italian, 121	428	Papua, 10
381	Scotch, 16; Guanche, 10	430	New Caledonia, 10
382	English (modern and uncertain date), 23	433	Negro, West Coast Africa, 20; [N. Australian, 6]
383	Indo-Malayan Archipelago, 20	439	Tasmanian, 10
385	Hindus, 20; Veddahs and Ceylon, 20	440	Kaffir, 16
386	Andaman Islands, 10	446	East Australian, 10
387	Scandinavian and Lapp, 10	450	New Hebrides, 10
388	Peru, 32	456	South Australian, 10
390	Greece, 19; Maduras, 20.		
391	Chinese, 19		
394	West Coast North American Indians, 20		
395	Mediterranean Mohammedans, 14; Ancient Egyptians, 38		
397	[Burmese]		
399	Polynesia, 17; Bushmen, 10		
400	Patagonia and Tierra del Fuego, 10	460	

TABLE II.—*To Illustrate Result 2.*

The numbers are values of [L] in $\frac{mm}{10}$.

EUROPE.	ASIA.	AMERICA.	AFRICA.	AUSTRALIA.
354. Irish				
360.				
363. Pre-Celtic-British				
369. Romano-British				
370.		370. [Vancouver I., deformed]		
373. French				
375. Anglo-Saxon				
380. Italian				
381. Guanche—Scotch				
382. English	383. Indo-Malayan Archipelago			
	385. Veddahs and Ceylon, Hindus			
	386. Andaman Is.			
387. Scandinavian and Lapp		388. Peru		
390. Greece	390. Maduras			
	391. Chinese			
395. Mediterranean Mohammedans		394. W. Coast N. Am. Indians	395. Ancient Egyptian	
	397. [Burmese]	395.		
	400.	400. Patagonia and Tierra del Fuego	399. Bushmen	399. Polynesia
	404. Japan	407. Guiana and Colombia		
		413. Esquimaux	410.	413. Maori
			420. Negro, East Coast	
			421. Zulu	
				425. Fiji Islands
				428. Papua
				430. New Caledonia
			433. Negro, West Coast	433. [N. Australia]
			440. Kaffir	439. Tasmania
				446. East Australia
				450. New Hebrides
				456. South Australia
				457. [W. Australia]

TABLE IV.—*To Illustrate Result 5.*

Percentages of cases in each race in which L-W is not greater than 2 mm. In this and the following table L and W refer to individual and not to average measurements.

70. French, Guanche.	53. Peru, Irish, Scotch.
69. British Islands, Pre-Celtic British.	50. Italian, Zulu, Bushmen, Chinese.
68. Indo-Malayan Archipelago.	46. Anglo-Saxon.
65. Hindus, Maoris.	45. Maduras, Veddahs, and Ceylon.
64. Polynesia.	44. Tasmania, Fiji.
61. Scandinavian and Lapp.	30. West Coast North American Indians,
60. Ancient Egyptian, Patagonian, and Tierra del Fuego.	South Australian, North Australian,
58. Greece.	New Caledonian, New Hebrides,
57. Romano-British, Mediterranean Mo- ammedans.	Kaffir, Negro, East Coast.
55. Esquimaux.	21. Negro, West Coast.
54. Japan.	20. Papua, East Australia.
	10. Andaman Islands.

TABLE V.—*To Illustrate Result 5 (latter portion).*

Table of Percentages in which L-W does not exceed 2 mm.

EUROPE.	ASIA.	AMERICA.	AFRICA.	AUSTRALIA.
70. French, Guanche				
69. British Is., Pre-Celtic-British	68. Indo-Malayan Archipelago			
65.	65. Hindus			65. Maori
				64. Polynesia
61. Scandinavian and Lapp		60. Patagonia and Tierra del Fuego	60. Ancient Egyptians	
58. Greece				
57. Romano-British, Med. Moham.		55. Esquimaux		
	54. Japan	53. Peru		
53. Irish-Scotch	50. Chinese		50. Zulu, Bushmen	
50. Italian	45. Maduras, Veddah, and Ceylon			
46. Anglo-Saxon		30. West Coast N. Am. Indians	30. Negro, E. Coast, Kaffir	44. Tasmania, Fiji
			21. Negro, W. Coast	30. New Caledonia, New Hebrides, S. Australia
	10. Andaman Is.			20. East Australia, Papua

A PLEA FOR UNIFORMITY IN THE DELIMITATION
OF THE REGIONS OF THE ABDOMEN. By
WILLIAM ANDERSON, F.R.C.S.

(Read before the Anatomical Society, May 23, 1892.)

As the plan of segmenting the ventral surface of the abdomen by means of two horizontal, and two vertical or nearly vertical lines, has survived the test of time, it might be assumed that it is a resource of some practical value to the physician and surgeon, and yet at the present moment, despite our recent advance in topographical anatomy, the teacher who refers to a particular abdominal area can never be certain that the name by which he designates it will convey the same impression to his hearers as to himself. The reason of this difficulty is not far to seek.

It is a rather curious fact that, although the nine historical regions of the abdomen have been universally accepted in British and continental schools for at least forty years, and may be traced back to a very much more remote period, no attempt has ever been made to secure uniformity in the plan of their delimitation, but almost every anatomical writer has elected to follow a system of his own, and, consequently, we have at the present moment at least fourteen different schemes in our recognised text-books. It can scarcely be necessary to argue upon the inexpediency of our position, and the desirability of securing accord amongst the teachers of anatomy.

The appended table shows the rules laid down by most of the principal authorities. On analysing this we see that the *upper horizontal line* may be drawn either (1) between the 9th costal cartilages of the two sides—the precise part of the cartilage, which forms about 2 inches of the border of the thorax, being usually left undefined (Gray, Todd, Turner, Holden, Heath, Shield, Tillaux); (2) between the 10th costal cartilages (Macalister, Aitken, Joessel); between the lowest points of the thoracic border, usually the 11th costal cartilage (Quain, Cunningham, Henle); or (3) on a level with the tips of the 12th ribs (Hyrtl, Rüdinger). The *lower horizontal line* may be drawn (1) either:

at the level of the highest point of the iliac crest (Quain, Gray, Turner, Cunningham, Henle, Bellamy, and others), or (2) between the anterior superior iliac spines (Todd, Holden, Heath, Macalister, Shield, Tillaux, Hyrtl, Rüdinger, and Joessel). *The longitudinal line* on each side may run upwards (1) from the middle of Poupart's ligament (Quain, Gray, Turner, Heath, Tillaux); (2) from the inner part of the ligament (Todd, Rüdinger); (3) from the pubic spine (Aitken, Macalister); or (4) from the anterior superior iliac spine (Hyrtl); (5) from the ilio-pectineal eminence (Joessel). It may be directed perpendicularly upwards without reference to any terminal point (Quain, Cunningham, Tillaux), or it may be drawn to a fixed, but often rather indefinite, locality above, as the 7th costal cartilage (Heath, Bellamy); the bony extremity of the 6th or 7th rib (Rüdinger); "the extremity of the 7th or 8th rib" (Todd); "the 8th costal cartilage," without reference to the particular part of the structure (Gray, Holden, Macalister, Shield); to "the 9th or 10th rib" (Henle); to the sternoclavicular joint (Hyrtl); to the acromio-clavicular joint (Aitken, &c.); or may stop short at the superior horizontal line, the upper region being subdivided by the costal border (Joessel).

Setting aside the impracticability of some of these indications, it is obvious that the variations between the different systems are really important. For example, in the scheme most in vogue, that adopted in *Quain's Anatomy*, the umbilicus lies at the lowest limit of the umbilical region, or even outside it altogether—never in the middle as the diagrams depict—and the height of the area seldom exceeds 2 inches, and is often less; in *Gray's Anatomy* the elevation of the upper horizontal line to the 9th costal cartilage adds an inch or two above; and in Macalister and Tillaux the depression of the lower horizontal line to the iliac spines lends an increase of about 3 inches in the other direction, and the umbilicus now falls in the centre of the area from which it takes its name. Again, in most of the systems the outline of the region is rectangular, or nearly so; but in Aitken it widens above towards the points of the shoulders, and in Hyrtl it widens below towards the anterior inferior iliac spines. Equally serious discrepancies exist in all of the other regions.

DELIMITATION OF THE REGIONS OF THE ABDOMEN. 545

	Upper Horizontal Line.	Lower Horizontal Line.	Vertical Line (on each side).
Quain, . . . Cunningham, . . .	{ Level of lowest part of wall of thorax on each side.	Highest point of iliac crest.	Upwards from middle of Poupart's ligament.
Gray, . . .		Do. do.	From cartilage of 8th rib to centre of Poupart's ligament (the two lines parallel).
Bellamy, . . .	Do. do.	Do. do.	7th costal cart. to mid. of Poupart's ligament.
Holden, . . . Shield, . . .	{ Do. do.	Ant. sup. iliac spines. {	8th costal cart. to mid. of Poupart's ligament.
Todd, . . .		Do. do.	Ant. extrem. of 7th or 8th rib to a point a little ext. to pubic spine.
Turner, . . .	Most prominent part of 9th costal cartilage.	Summit of iliac crest.	Perpendicular line upwards from middle of Poupart's ligament.
Heath (4th ed.), . . .	Through 9th costal cartilage.	Ant. sup. iliac spines.	From 7th costal cart. to mid. of Poupart's ligament.
Macallister, . . .	From 10th costal cart.	Do. do.	From 8th costal cart. to pubic spine.
Atken, . . .	Do. do.	Do. do.	From acromio-clav. joint to pubic spine.
Tillaux, . . .	Through 9th costal cartilage.	Do. do.	From ilio-pect. eminence or middle of Poupart's ligament vertically upwards.
Henle, . . .	Deepest point of border of 10th rib.	Highest point of iliac crest.	From 9th or 10th rib down to middle of Poupart's ligament.
Hyrtl, . . .	Tip of 12th rib.	Ant. sup. iliac spines.	From sterno-clav. joint to ant. sup. spine of ilium.
Rüdinger, . . .	Do. do.	Do. do.	From bony end of 6th or 7th rib to inner portion of Poupart's ligament.
Joessel, . . .	Cartilaginous end of 10th rib.	Do. do.	From ilio-pect. eminence perpendicularly upwards to upper horizontal line. Epigastric region separated from hypochondria by costal borders.
	(Posterior aspect subdivided into three regions, vertebral and right and left lumbar.)		

This is chaos, and there is little doubt that it were better to abandon the pretence of a regional subdivision of the abdomen altogether than to employ terms which have no scientific meaning.

I have no wish to complicate confusion by proposing a fifteenth system, and I should be glad to welcome any scheme

of delimitation that meets with the approval of this Society. Whatever plan be framed, however, it is desirable that the boundary "lines" should be converted into planes carried through the whole depth of the abdomen, and defined on the dorsal as well as on the ventral surface of the trunk, and that the structures cut through by these planes should be noted, as well as those comprised within the regions which they separate. It should, of course, be recognised that the relations so defined can only be approximate, on account of the wide range of physiological variation in the position of the abdominal contents; but this being understood, a regional type would be of material service in medical education.

If, then, we retain the subdivision into nine segments, it remains only to discuss the method of delimitation. Firstly, for the horizontal planes, the most ancient system and perhaps the best, is that quoted in Le Clerc's *Epitome of Surgery* (published in English in 1696). Here the linea alba is subdivided into three equal parts, and the superior horizontal line lies at the junction of the upper and middle thirds, the inferior at the junction of the lower and middle thirds. To take, however, more modern authorities, the most suitable level for the *higher plane* appears to be that adopted in *Quain's Anatomy*, the lowest point of the cartilaginous border of the thorax (usually the 11th costal cartilage). This plane passes through the second lumbar vertebra posteriorly, and lies about 2 inches above the umbilicus in front; but the 8th and 9th costal cartilages are objectionable as indications for level, because each forms two inches or more of the thoracic border, and neither can be satisfactorily defined through the integuments in stout persons. For the *lower horizontal plane* we have the choice of two levels—that of the highest point of the iliac crest, corresponding to the lower part of the 3rd lumbar vertebra, and that of the anterior superior iliac spine, which lies about an inch below the level of the sacral promontory. It is hard to say which offers the greater advantages. The objection to the former is that it frequently excludes the umbilicus from the umbilical region, and reduces the middle zone (lumbar and umbilical regions) to a very narrow segment of the abdomen. On the other hand, the lower plane, that of the iliac spines,

leaves a large portion of the iliac fossæ in the lumbar regions, and it confines the iliac regions within a very restricted area. On the whole, however, it seems the more convenient as it leaves the umbilicus nearly in the middle of the umbilical region, where, with strange unanimity, it is figured in the diagrams of every system; and its boundary lines touch some structures of much surgical interest.

For the *longitudinal plane* on each side, that corresponding to the vertical line of Quain, running upwards parallel to the mesial line from the middle of Poupart's ligament, would be the most practical, as it can be readily localised by the eye without the necessity of searching for uncertain or imperceptible costal landmarks, and is already familiar to the greater number of observers.

Could we cast off tradition without loss, it would, perhaps, be more simple, and hence more useful, to divide the cavity into superior and inferior segments by a single horizontal plane at the level of the umbilicus (or of the highest point of the iliac crest), and then to subdivide each segment into three by two vertical lines drawn as described, from the middle of Poupart's ligament. The regions might then be called right, left, and middle superior, and right, left, and middle inferior; but such a change would have the great disadvantage of making the older references unintelligible.

It is quite unnecessary to occupy the time of the Society with any review of the contents of the regions, or of the parts cut through by the imaginary delimitation planes. This can be done when an agreement is arrived at; and all that is attainable in accuracy of localisation may be secured by the aid of sections of the frozen body. Professor Cunningham, who has done so much for practical as well as for scientific anatomy, has already commenced the work in the admirable series of casts which were exhibited here two years ago, and are again before us to-day.

I trust the Society may see fit to take up the question. Whether any combined action of British anatomists would affect the continental schools may be open to doubt, but much will be gained if we are able to agree amongst ourselves.

NOTE ON THE ANATOMY OF THE SUPRARENAL BODIES. By H. D. ROLLESTON, M.A., M.D., Cantab., Fellow of St John's College, Cambridge, *Pathologist and Lecturer on Pathology at St George's Hospital*.¹ (PLATE XIII.)

THE anatomical relations of the suprarenal bodies are so much more easily seen in the *post-mortem* room than in the dissecting room, that I venture to bring forward the results of observations made in the *post-mortem* room of St George's Hospital.

RIGHT SUPRARENAL.

The right suprarenal capsule embraces the inner and upper part of the kidney, overlapping its surface, lying on the crus of the diaphragm, and under cover of the peritoneum, the liver, and inferior vena cava. The outline of the right suprarenal, as seen from the front, is roughly triangular; its angles point respectively (1) outwards, (2) upwards, and (3) downwards.

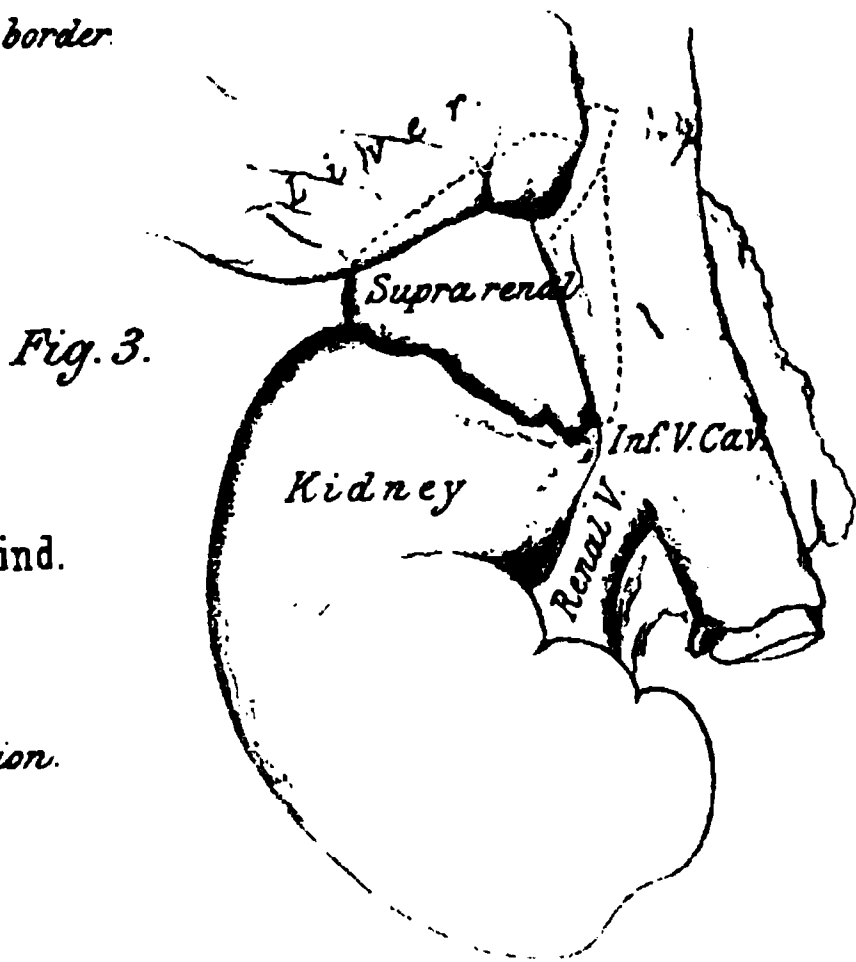
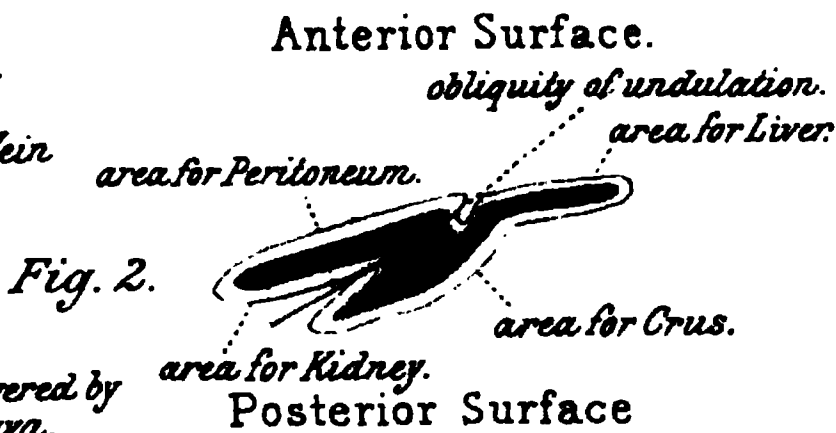
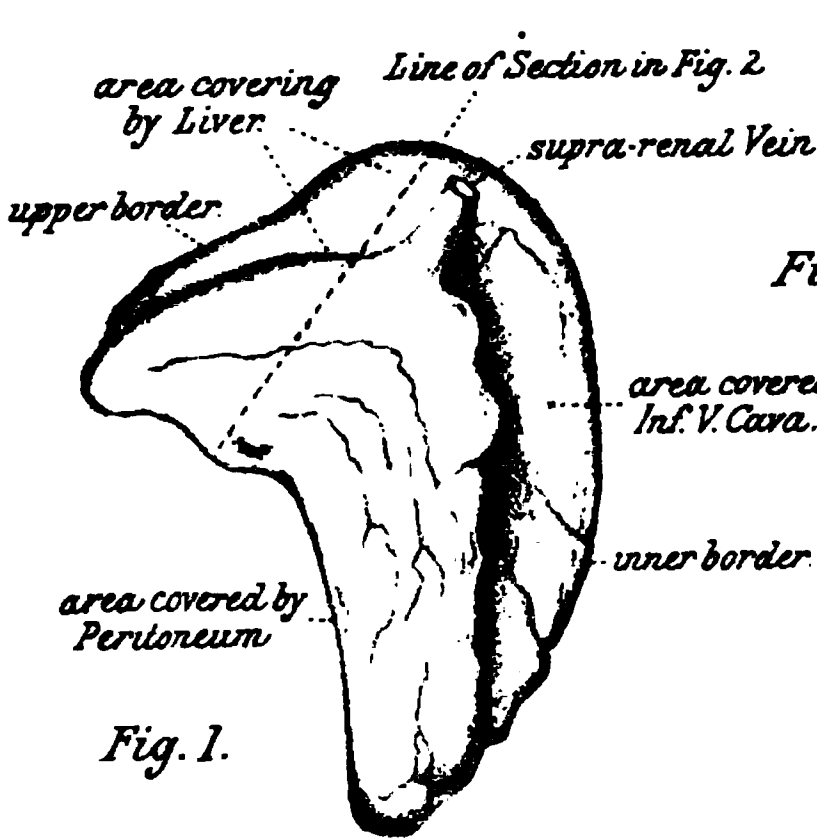
It is flattened and represents two chief surfaces, anterior and posterior, each of which are divisible into two secondary areas. The anterior surface, however, is not uniformly flat.

Along its upper and inner borders part of the anterior surface is depressed below the level of the remainder. The whole depressed area forms a varying proportion, one-third to a half, of the whole anterior surface, usually a third. Separating these two areas is a furrow with an elevation external to it; the elevated portion is flattened and bent forwards (*vide* fig. 1).

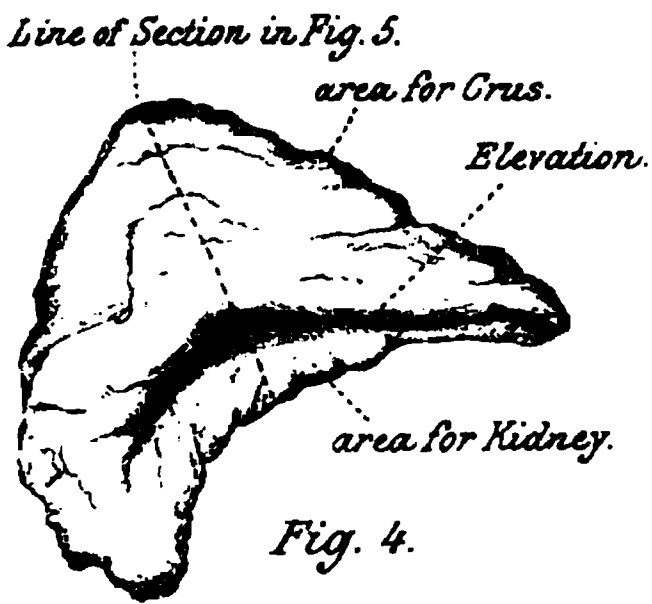
Sections of the suprarenal body show that the furrow corresponds to a projection (fig. 2), and the elevation to a groove on the posterior surface.

This undulation on the anterior surface follows the same curve as that of the convexity of the upper and inner borders of the suprarenal body. At the junction of the upper and inner

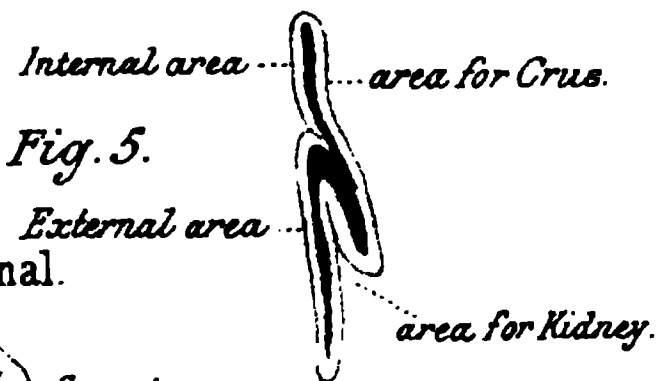
¹ Communicated to the Anatomical Society of Great Britain and Ireland, May 23, 1892.



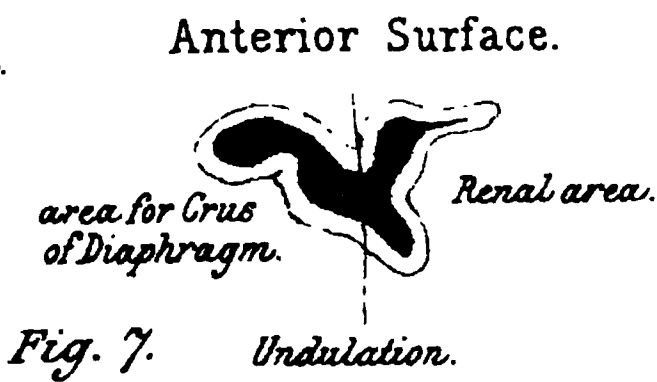
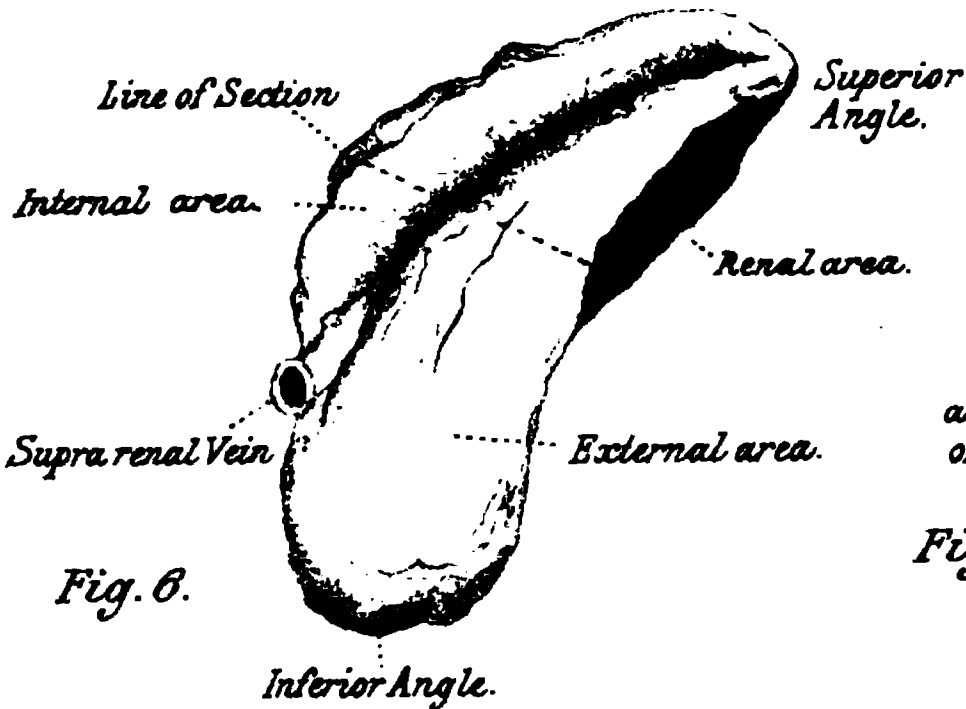
Posterior Surface of Right Suprarenal from behind.



Relations of the Right Suprarenal.



Anterior Surface of Left Suprarenal.



limbs of this undulation the suprarenal vein arises and runs upwards and inwards to join the inferior vena cava.

The depressed area is not in contact with peritoneum; the part which lies adjacent to the upper border is in contact with the under surface of the right lobe of the liver (fig. 3), while the part along the inner border is underneath the inferior vena cava (fig. 3), and separated thereby from the first part of the duodenum.

The remaining or elevated portion of the anterior surface is underneath the reflection of peritoneum, which passes from the upper part of the kidney to the under surface of the right lobe of the liver (hepato renal fold). This raised portion of the anterior surface is over that portion of the posterior surface which lies on the upper and inner part of the kidney, while the depressed area is over the portion of the posterior surface which lies on the crus of the diaphragm.

Owing, however, to the obliquity of the undulation (fig. 2) in the suprarenal, these corresponding surfaces, viz., (1) depressed region on anterior surface and impression for crus on posterior surface, and (2) raised peritoneal area on anterior surface and impression for kidney posteriorly, are not of the same size, but, roughly speaking, vary inversely. The raised peritoneal surface is the larger on the anterior surface, while the surface for the kidney is the smaller on the posterior surface (*vide* fig. 2).

On the posterior surface (*vide* figs. 4, 5) the undulation seen on the anterior aspect is much more marked, the elevation being bigger and not so bent over (*vide* figs. 2, 5). As a result, the posterior surface is not so flattened as the anterior surface, and is divided into two secondary areas, which do not lie in the same plane, and which join at a somewhat obtuse angle (fig. 2). The outer and smaller area looks backwards, but is so tilted forwards by the underlying kidney that it looks also downwards. The inner larger surface is directed backwards, and is flattened on the crus of the diaphragm (fig. 4).

The undulation is the prominent boundary between the two secondary areas on the posterior surface. The two secondary posterior areas in early life appear so distinct as to suggest a description of three surfaces to the suprarenal body—viz.,

anterior, posterior in contact with the crus of the diaphragm, and an inferior in contact with the kidney. In adult life, however, the suprarenal thickens, and this appearance is less prominent. A description of anterior and posterior surfaces, which are each divisible into two by an undulation, is perhaps preferable, and, as will be seen later, renders the description of the two suprarenals more alike.

The presence of the undulation is due to this body being packed between the liver and inferior vena cava in front, which tend to depress the surfaces they are in contact with, and the kidney behind, which presses the rest of the anterior surface into a prominent position, while the space between the crus and the kidney is responsible for the projecting spur of the undulation posteriorly.

The obliquity of the undulation (*vide* fig. 2) may be due to the differences of the surfaces which exert pressure on the anterior and on the posterior surfaces respectively of the suprarenal body.

Anteriorly, the inferior vena cava, the part of the liver uncovered by peritoneum, and the peritoneal surface of the right lobe of the liver, present a fairly uniform surface, which flattens out the whole of the anterior surface of the suprarenal, and prevents what would be the spur of the undulation from projecting much above the general surface of the organ.

Posteriorly, on the other hand, there is a notch between the crus of the diaphragm and the kidney, which receives the spur of the undulation, and allows it to be a fairly prominent feature on this surface.

THE LEFT SUPRARENAL.

The left suprarenal body lies along the inner margin of the upper half of the kidney, which it overlaps; it passes on to the upper margin of the kidney for a short distance only.

The outline, as viewed from the front (*vide* fig. 6), is roughly crescentic, with the inferior angle rounded. The internal border is convex, and looks inwards and slightly upwards, while the concavity or outer border is in contact with the kidney.

There are two angles—the superior, directed slightly outwards, and the inferior.

There are two surfaces, anterior and posterior, each of which are divided into internal and external areas (figs. 6, 7). The anterior surface is in contact superiorly with the spleen above the point where the posterior portion of the internal surface of that organ is moulded on the kidney. Internally to the spleen the cardiac extremity of the stomach, close to the entrance of the œsophagus, lies in contact with this surface. This part of the suprarenal body is covered by the peritoneum lining the lesser sac of the peritoneum.

The lower half of the anterior surface is covered by the pancreas and splenic artery, and so is not in contact with the peritoneum.

The lower border of the suprarenal can, however, be seen under the peritoneum, at the lower border of the pancreas, when that organ is slightly displaced upwards.

The anterior surface is flat, and is traversed by a deep groove, from which the suprarenal vein runs downwards to join the left renal vein.

This groove runs from above downwards and inwards, dividing the anterior surface into (*a*) an outer and inferior, and (*b*) upper and inner areas. Near the superior angle these areas are equal, but below the outer becomes the larger (fig. 6), and forms the lower rounded extremity of the suprarenal.

On the posterior surface there is a projection (fig. 7) produced by the groove on the anterior surface, which passes almost at right angles to the plane of the anterior surface between the crus of the diaphragm and the kidney. This undulation in the left suprarenal body is vertical, and not oblique as in the case of the right suprarenal body. Hence the areas on the anterior and posterior surfaces which it produces correspond to each other in size.

On the posterior surface there is a larger area, directed backwards and outwards, which fits on to the kidney, separated by the undulation from the small area for the crus of the diaphragm, which looks inwards and backwards. Internally the suprarenal is thick, while externally it is thin and expanded. The external area just overlies the renal vessels in the hilum of the kidney; the internal area may just cover the outer

border of the left semilunar ganglion, but this is not a constant relation.

The difference in the undulations in the two suprarenals evidently depends on some difference in the packing of the two organs, and the most probable explanation of the more complicated form of the undulation on the right side is the close relation of the firm liver and the considerable pressure exerted thereby on the suprarenal.

Of the two suprarenals, the right is usually flattened and expanded, while the left is compact. Sometimes, however, the right is compressed, and tends to resemble the left in form.

Numerous weighings showed that both suprarenals averaged about a drachm, the left being rather the heavier.

For the Drawings which illustrate this communication I gratefully acknowledge my indebtedness to G. H. Goldsmith, B.A., a senior student of St George's Hospital.

ACCESSORY SUPRARENALS.

Small accessory suprarenals are often present in the connective tissue around the suprarenals. They are usually round and quite small. They are often multiple. The largest I have seen were rather bigger than a cherry-stone. There are not unfrequently small white elevations on the surface of the suprarenals, like split peas, composed of suprarenal cells in a more marked stage of fatty infiltration than is usually met with in the cells of the cortex, which, however, in the adult normally show fatty infiltration. They have been called Adenomata.¹

Accessory suprarenal bodies differ from these adenomata in being separate from the suprarenal, and in possessing a capsule of their own, and in showing little fatty infiltration.

On section, some of the accessory suprarenals, especially the smaller ones, show a uniform surface, and no distinct medulla can be made out, either by the naked eye or by the microscope.

This agrees with Duckworth's observations (*St Bartholomew's Hospital Reports*, vol. i. p. 230). However, the larger accessory suprarenals show on section, both to the naked eye and the microscope, a central medulla.

¹ Wilks' *Pathological Anatomy*, p. 510.

On one occasion I found the suprarenal body to be partially outside and partially inside the kidney. Microscopic sections showed the fibrous capsule of the kidney fading away, and leaving the elements of the kidney and suprarenal body in contact, with no distinct line between the two.

The presence of accessory suprarenals embedded in the substance of the kidney has been described by German Anatomists and Pathologists.

EXPLANATION OF PLATE XIII.

Fig. 1. Anterior surface of right suprarenal, showing elevated area covered by peritoneum, and depressed area in contact above with the liver and internally with the inferior vena cava. Undulation separating depressed and elevated areas. Suprarenal vein running upwards and onwards to open into the inferior vena cava. Three borders; three angles. Line of section seen in fig. 2.

Fig. 2. Section of right suprarenal as seen on face of small portion external to line of section in fig. 1. The obliquity of the undulation is shown. The anterior surface is divided into smaller area for direct contact with liver and inferior vena cava, and larger elevated area for peritoneum. The posterior surface, divided into smaller area for kidney and larger area for the crus of diaphragm.

Fig. 3. Anatomical relations of right suprarenal body; the anterior border of the liver has been raised so as to expose the suprarenal. Depressed area in outline seen in contact with and under the inferior vena cava and the liver.

Fig. 4. The right suprarenal body from behind. Larger area for crus, situated above and internally. Smaller area for kidney, below and externally. Undulation separating the two areas. The line of section, which is shown in fig. 5.

Fig. 5. Showing cut end of that half of the right suprarenal which in fig. 4 lies to the right of the drawing. Anterior surface, smaller internal depressed area and larger external elevated area. Posterior surface, larger internal area for crus, and smaller external area for kidney.

Fig. 6. Anterior surface of the left suprarenal body. The external area on the posterior surface is represented deeply shaded. Groove with suprarenal vein. Superior pointed angle. Inferior rounded angle. Internal smaller area. External larger area. Line of section, represented in fig. 7.

Fig. 7. Showing lower end of the upper piece cut across in section indicated in fig. 6. The undulation in the suprarenal is nearly vertical to the plane of the anterior surface. On posterior surface—internal area for crus, external area for kidney.

NOTE ON THE ABSENCE OF THE SUBCLAVIUS MUSCLE.

By J. W. CRERAR, M.B., *Demonstrator of Anatomy, University, Edinburgh.*

THIS abnormal condition was discovered in a well-developed, muscular, adult female subject, in the dissecting room of the University of Edinburgh, during the winter session 1891-92. On the *left* side the subclavius muscle was replaced by a strong fibrous band extending from the upper border of the first rib, just external to its osteochondral junction, to the inferior surface of the clavicle external to the attachment of the rhomboid ligament, with which it was continuous. The costo-coracoid membrane was complete, and was prolonged downwards as a thin layer to the upper border of the pectoralis minor. It was continuous superiorly and internally with the fibrous band before mentioned. It was traversed by the usual structures—that is to say, by the cephalic vein, acromio-thoracic branches of the axillary artery, and the external anterior thoracic nerve. The pectorales major and minor were similar, and normal in size and attachments on both sides. The clavicle was slender, 153 mm. long, and, but for the absence of a distinct subclavian groove, was otherwise normal. The upper part of the chest wall displayed no abnormality of shape. Microscopic examination of a portion of the fibrous band revealed no trace of muscular fibre.

The *right* subclavicular region was normal in all respects.

Kölliker¹ records a case where a similar condition obtained—the subclavius of the left side being replaced by a ligament; and Gruber² notes the total absence of the subclavius muscle in an abnormal foetus.

CASES OF MECKEL'S DIVERTICULUM. By T. N. KELYNACK, M.B., Ch.B., *Pathologist, Manchester Royal Infirmary; Demonstrator and Assistant Lecturer in Pathology, The Owens College.*

As a supplementary note to the recent report of the Collective Investigation Committee of the Anatomical Society,³ a brief record of the following cases of Meckel's diverticulum, observed in the Post-Mortem Theatre of the Manchester Royal Infirmary during the last few months, may be of interest.

Among the last 298 cases (213 males, 85 females), where abdo-

¹ Quoted by Testnt, *Anomalies Musculaires*, 1884, p. 46.

² *Virchow's Archiv*, vol. xl. p. 434.

³ *Jour. of Anat. and Phys.*, Oct. 1891, p. 91.

minal examination was made, 4 cases of diverticulum ilei (Meckel's) have been noted, all in males. Subjoined are brief descriptions:—

Case 1.—Male, æt. 58. Death from suppurative peritonitis resulting from perforation of chronic round ulcer of the duodenum.

Meckel's diverticulum¹ present as a small nipple-shaped *cul-de-sac*; situated 40 inches above cæcum.

Case 2.—Male, æt. 34. Death from "stone-masons' phthisis."

Meckel's diverticulum,² 5½ inches long; contains no fæces; situated 21 inches above ileo-cæcal valve. A fibrous-like cord anchors tip of fundus to parietal peritoneum, just a little behind and below bladder. It would appear as though this cord of attachment might have broken away from umbilicus or abdominal wall, and subsequently have contracted fresh adhesion to present site. By this attachment an arch, or rather ring, is formed, through which intestine might readily have become herniated.

Case 3.—Male, æt. 42. Alcoholic subject, death from acute croupous pneumonia.

Meckel's diverticulum,² 3½ inches long, 2 inches wide; distended with gas, and containing no fæces; free, no adhesions; situated 40 inches above ileo-cæcal valve.

Case 4.—Male, æt. 53. Death from latent gastric carcinoma.

Meckel's diverticulum, 1½ inch long; nipple-shaped; distended with gas, and containing no fæces; projecting freely; situated in umbilical region, 36 inches above cæcum.

ADDITIONAL NOTE ON BIFURCATION OF THE FEMORAL ARTERY. By JAMES MUSGROVE, M.D., M.R.C.S., *Demonstrator of Anatomy, Edinburgh University.*

IN connection with a case of Bifurcation of the Femoral Artery recently recorded in this *Journal*,² I published a table showing the examples which had previously been described, and included the case by Ducachet (No. 6 in the list) cited by Henle, at the same time expressing doubt about it. Since then, I have received, through the kindness of Mr J. G. Rodger of New York, the account of the case as originally published in the *American Medical Times*, March 1863, which justifies the doubt then expressed. The account reads as follows:—"Henry Klumpater, private of Company 18th, New York Vol's, received a shell wound Aug. 30.62. The patella and outer condyle of the femur, with a considerable portion of the Tibia, were carried away. He was admitted, Sept. 9th, to Fairfax Seminary Hospital. Amputation was performed Sept. 17th under chloroform. On account of the enormous size of the leg due to swelling, and the

¹ Specimen in Pathological Museum of The Owens College.

² *Jour. of Anat. and Phys.*, vol. xxvi. (n.s. vol. vi.), pt. 2.

difficulty, when such is the case, in controlling the hæmorrhage with the tourniquet, it was thought best to secure the femoral with a ligature before amputation. The surgeon in charge (Dr D. R. Smith), on making the section of the upper flap, cut an artery the size of a large quill, which bled profusely. The patient died on the 21st, and dissection showed the existence of two femoral arteries. The one that had been ligatured was in its normal position with the profunda given off at its usual place. The other was of nearly the same size, and given off just below Poupart's ligament. The two were distant at the point of ligation about two inches."

From the description it is evident that this is not a case of bifurcation of the femoral, but rather an example of a *vas aberrans*, such as is represented by Tiedemann in one of his plates.¹ Because it will be observed that the two vessels were not close together, but separated by a distance of two inches, and the division took place close to Poupart's ligament, and not, presumably, below the origin of the profunda. Ducachet's case must, therefore, be removed from the list.

¹ *Tab. Art. Corp. Hum.*, Taf. li. fig. 2.

MACRODACTYLY, AND SOME OTHER FORMS OF CON-
GENITAL OVER GROWTH, AND THEIR RELATION TO
TUMOURS. BY Sir GEORGE MURRAY HUMPHRY, M.D., LL.D.,
F.R.S., *Professor of Surgery in the University of Cambridge.*

(Read at the Royal Medico-Chirurgical Society of London, February 10, 1891,
and reprinted from vol. lxxxiv. of the Society's *Transactions*.)

IN the Pathological Museum of the University of Cambridge are the
six following specimens and casts :—

1. The hypertrophied second toe amputated from a child æt. 4,
by Mr Morris, of Bishop-Stortford. At birth it was thrice the size
of the great toe, and grew more rapidly than the other parts. The
phalanges are of great length, but not otherwise diseased. The
tendons are proportionately large, and there is a superabundance of
skin and adipose tissue all round.

2. A cast presented by Mr C. W. Cathcart, of Edinburgh, of the
giant middle finger of a child æt. 20 months. The condition was
congenital ; but the finger had grown out of proportion to the other
fingers, and was amputated by Mr Joseph Bell.

3. A cast presented by Mr C. W. Cathcart of the great toe of a girl
æt. 13. The affection was congenital. The second toe had still larger
proportions, and was amputated in childhood.

4. A cast, taken and presented by G. May, of Trinity College, of
the left foot of a woman æt. 45, in the London Hospital. The two
inner toes and the inner side of the foot hypertrophied from birth.

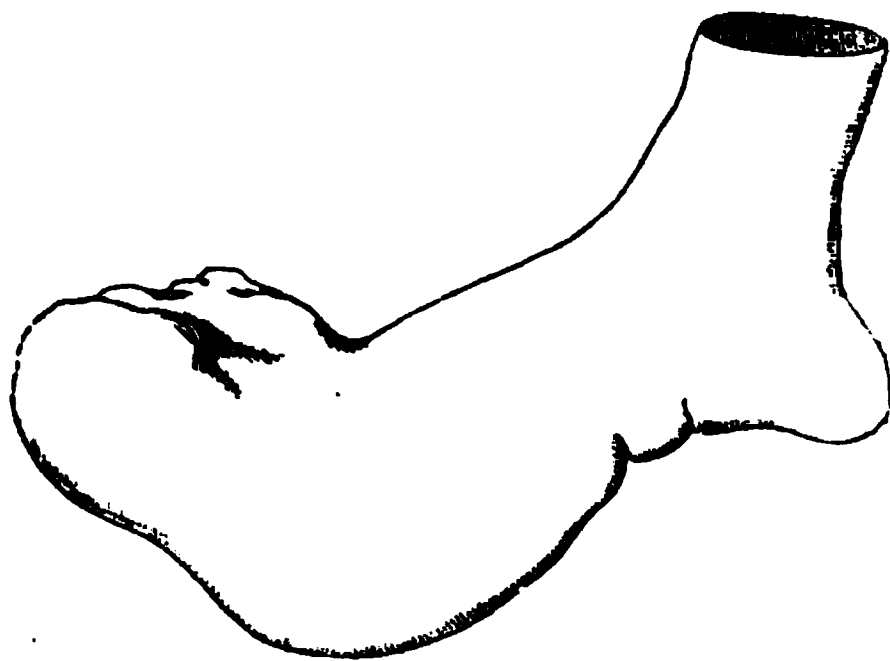
	Left foot.	Right foot.
The inner border of the foot from the point of the heel to the end of the great toe . . .	13½ in.	10 in.
Circumference of great toe near the end . . .	7	2½
„ of second toe „ . . .	5	1½
Outer border of foot	7	7

The sole is flat, and bulges on the inner side as in “flat-foot.”
No similar condition in any member of her family or any of her
children.

5. A cast of congenital hypertrophy of the fore and middle fingers
of the right hand of a boy æt. 12. The forefinger measures from the
metacarpal bone four inches and a half, the second and third phal-
anges measuring two inches and three quarters, circumference of
thickest part three inches and three quarters. The middle finger
measures three inches and three quarters in length, in circumference
three inches, and is remarkably deflected towards the ulnar side in the
second and third phalanges. The thumb and other fingers normal.
The cast was presented by Dr T. J. Walker, of Peterborough, who am-
putated the two hypertrophied fingers because they were stiff, much
in the way, and a source of mortification to the boy. The growth

was not disproportionate to that of the other fingers. There was no similar condition in any member of the family.

6. The cast of the foot of a lad æt. 9, whom I saw on the beach at Cromer in 1837, and whom I took to the Norwich Hospital, where he was under the care of Mr Crosse, whose apprenticed pupil I then was. The enlargement, as seen in the accompanying rough sketch, was great, and affected the three inner toes of the right foot. It was congenital, and proceeded with a rapidity out of proportion to the general growth ; and it was extending upon the sole more mani-



festly than in any other direction. The two outer toes were rather smaller than the corresponding toes of the other foot. The mass appeared to be chiefly composed of fat covered with rather coarse skin, and the nails of the hallux and second toe were much larger than natural. The affected toes were much extended, and the extensor tendons tight. No tenderness or pain. The muscles of the leg were enlarged, and the lad could run about as well as other boys. His father, mother, brothers, and sisters were fine, well-made persons. The hypertrophied parts, being unsightly, cumbrous, and increasing, were removed by Mr Crosse, the ends of the enlarged metatarsal bones being taken away, and sufficient skin saved from the dorsum of the foot to cover the sole and leave a good

useful foot, with little deformity or inconvenience. It was necessary to dissect out the fatty substance which extended up between the metatarsal bones. The mass was composed mainly of adipose substance. The bones were enlarged, but not otherwise diseased. The specimen, from which, however, the bones have been removed, is in the museum of the Norwich Hospital; and Mr Thomas Crosse, the indefatigable curator of the museum, was good enough to take it out of the bottle the other day and verify my recollections of it.

Curling¹ records the case of a girl (No. 7) in whom the fore, middle, and ring fingers of the right hand, and the thumb, index, and middle fingers of the left hand were greatly hypertrophied, all the parts—bones, articulations, integuments, and nails—being developed in excess. The middle finger of the left hand was remarkably curved outwards (to the ulnar side), this having been “occasioned apparently by a displacement of the extensor tendon, which forms a bridle along the outer edge;” the movements of the fingers but little impaired. The fingers felt cold. Pulsation in the digital arteries indistinct. The fingers were remarkably large at birth, and had grown out of proportion to the rest of the body. He mentions the following:—(No. 8) A child aged two, seen by Professor Owen, with the middle finger of each hand twice as long and more than twice as thick as the index. (No. 9) A cast, with particulars by Sir James Paget, of the right hand of a man aged fifty, with hypertrophied first and second fingers; the second was of enormous size, and curved outwards as in No. 7. The parts bore the same proportion as at birth, and were not the cause of any inconvenience. (No. 10) The cast of the hand of an adult in the museum of King’s College, with the middle finger congenitally hypertrophied. The hands of other members of the family are reported to have been deformed in a similar manner. (No. 11) The case of a girl aged five, by Mr Power, of Dublin,² with the middle finger of the right hand much, and the index and ring finger somewhat enlarged, particularly the ring finger, which was divaricated from the middle in consequence of its abnormal growth. (No. 12) Dr John Reid³ gives the case of a boy aged thirteen, in whom there was increased nutrition of the thumb and first finger of the left hand. The enlargement was associated with enlargement of the radial artery, and elevation of temperature was observed at birth, and continued to increase. In this paper Dr Reid also describes the case (No. 13) of a lad aged fifteen, with congenital hypertrophy of the whole of the left upper limb including the scapula; and (No. 14) that of a girl aged two, with congenital hypertrophy of the middle toe, which equalled in bulk all the remaining four toes, the phalanges and metatarsal bone being of great size.

Busch, in an excellent article,⁴ relates two cases. One (No. 15) a man aged twenty, with congenital hypertrophy and deformity of the

¹ *Medico-Chirurgical Transactions*, xxviii. 337.

² *Dublin Journal of Med. Science*, xvii. 244.

³ *London and Edin. Monthly Journal of Med. Sc.*, 1843, p. 198.

⁴ *Langenbeck’s Archiv für klinische Chirurgie*, vii. 174, pl. vi.

three inner toes, which were much over-extended, and the adjacent part of the sole of the right foot, the growth proceeding out of proportion to the rest of the body, and advancing along the sole (resembling, in short, No. 6). Pirogoff's amputation was performed. The phalanges, metatarsals, and inner tarsal bones were enlarged, especially at their articular ends; and these were deformed, tuberculated, and in some instances ankylosed; the ligaments thick, and the synovial fringes pronounced; much and disproportionate increase of fatty tissue, causing deformity and bulk; the arteries and nerves unaltered; the dorsal veins in part greatly thickened by fibrous formation in concentric sheets in their walls without increase of lumen; two outer toes quite free from hypertrophic change; the small muscles of the foot thin and pale, but the tendons passing from the leg, especially that of the *tibialis posticus*, very thick; two small fat swellings in front of the tibia; the tibia and fibula rather larger but not thicker than those of the other leg; the thighs of equal length.

Busch's second case (No. 16) was a girl aged twelve, with hypertrophic condition of the second and third toes of the right foot, which were over-extended and projected beyond the other toes. Being inconvenient, unsightly, and disproportionately increasing, they were removed, and the projecting end of the second metacarpal was removed also. The hypertrophy of the bones affected chiefly their ends (the epiphyses). The capsular ligaments were very thick, and contained cartilage nodules near their attachments. The joints were in other respects normal, as also were the arteries, veins, nerves, and tendons. The fatty tissue on the dorsal as well as on the plantar aspect was much increased.

Busch quotes a case (No. 17, from Graefe¹) where Klein amputated an hypertrophied forefinger of the left hand (sex and age not given), the second and third phalanges of which projected laterally over the other fingers. No vessel required ligature at the time, though there was some bleeding afterwards; a case (No. 18) by Guersant² of hypertrophy of the fourth and fifth fingers; a case from Böhm³ (No. 19) of a girl aged sixteen, in whom the second toe of the left foot was three times as long and twice as thick as that of the other foot. The examination of the part when amputated showed nothing abnormal in the arteries and nerves. The plantar fat-pads were large, and the ligaments thick. (No. 20) Wagner⁴ describes the case of a lad (aged eighteen) in whom all the right hand (except the thumb, which was smaller than that of the left hand) and the forearm were hypertrophied, and grew out of proportion to the rest of the body. The end of the forefinger, which was small, was over-extended. The size was apparently due chiefly to fat-growths. There was also a fat-growth about the right breast, extending from the sternum to the axilla, which had begun when he was five years old. (No. 21)

¹ From *Graefe and Walther's Journal*, vol. vi.

² *Gazette des Hôpitaux*, 1857, p. 463.

³ *Inaugural-dissertation über Macrodactylie*, Giessen, 1856.

⁴ *Schmidt's Jahrbücher*, iii., Supplementband, 1842, s. 66.

Legendre, quoted by Böhm, saw a child aged four and a half with hypertrophy of the fourth and fifth fingers and the ulnar side of the hand, chiefly on the palmar aspect. The fourth finger was bent backwards and to the radial side in consequence of inequality of growth of the two sides. (No. 22) Ideler (in seiner *Dissertation*, Berlin, 1855) gives the case of a lad aged twelve, in whom there was hypertrophy of the three middle toes, including the metatarsal bones, of both feet, with lipomatous condition of the toes and soles and somewhat of the dorsa; several small lipomata in the left leg, and a large congenital lipoma in the left buttock. In consequence of the increasing deformity the fore parts of both feet were removed by amputation, and the metatarsals and phalanges of the three middle toes were of abnormal length. The other toes appear to have been rather undersized. (No. 23) Wulff¹ gives the case of a man aged thirty-two, in whose right hand the first three fingers (thumb, index, and middle fingers) were congenitally hypertrophied. The growth had continued *pari passu* with that of the rest of the body, but the increase had been greater in the last few years. There was much enlargement of the bones, especially in the neighbourhood of the metacarpo-phalangeal joint of the thumb, the terminal joint of the index, and both the phalangeal joints of the middle finger; external bending of the fingers, and great increase of the fat-tissue. The arteries were apparently alike in the two limbs. (No. 24) Burow² mentions a Polish girl aged six, with hypertrophy of the second and third toes with their metatarsals. The increase was proceeding quickly, and the parts were removed. (No. 25) Mr Holmes³ represents the cast of the left foot and leg of a child aged twenty months, affected with congenital enlargement of the foot and leg, which was so inconvenient and on the increase that amputation in the leg was performed, under the impression, he believes, that the disease was of malignant nature. Anatomical examination, however, showed that the bulk was due to an unusual deposition of fat and cellular tissue, the muscles as well as the bones being normal.

It appears from the above-recited cases (more might doubtless be collected) that the parts more frequently affected with this congenital "overgrowth," "hyperplasia," "hypertrophy," or "macroductyly," are the digits on the inner—the radial and tibial—sides of the hands and feet, more particularly the second and third digit in the hand, and the first, second, and third in the foot; though in some cases (Nos. 20 and 21) the other digits were affected. In Nos. 6 and 22 the unaffected digits were somewhat undersized. The adipose tissue, the bones, and the skin⁴ participated in the overgrowth, and usually in a proportionate degree; though in some the adipose tissue

¹ *Petersburger med. Zeitschrift*, 1861, 10 Heft, s. 281.

² *Deutsche Klinik*, 1864, No. 27.

³ *System of Surgery*, iii. 798.

⁴ I do not find it observed that the cutis or the cuticle was very thick, or the hair long or superabundant, in any of the cases, as is so often seen in "moles." The large size of the nails was a consequence of and proportionate to the large matrix from which they grew.

was increased to a disproportionate extent. The ligaments, the synovial fringes of the joints, and the tendons were in some observed to be enlarged. In No. 15 there was marked increase of the fibrous tissue in the coat of one of the veins. In this case also the articular ends of the bones were nodulated and deformed, and in one joint ankylosed, the parts thus presenting a resemblance to the condition often found in rheumatic arthritis, and to that sometimes observed in the acromegaly of adults. In the hand the condition was mostly limited to the digits, though in No. 13 the whole upper limb was involved; but in the foot it extended beyond the digits in several instances, the metatarsal bones of the foot and even the bones of the leg (No. 15) being enlarged. The affection showed an especial tendency to spread along the sole of the foot, and the adipose tissue to grow up between the metatarsal bones.

The various tissues, except in No. 15, were simply hypertrophied (overgrown), but not otherwise diseased; and no abnormal condition of the blood-vessels, save the thickening of the veins in No. 15, or of the nerves was discovered in any case. The over-extension of the toes noted in some was probably caused by the adipose growth on the plantar aspect exceeding that on the dorsal; and the lateral curvature observed in the fingers was probably due to an irregularity in the growth on their two sides, rather than, as suggested by Curling, to the influence of the extensor tendons.

In Nos. 7, 8, and 22 the condition was symmetrical, or nearly so. It occurred about equally in boys and girls, in the hands rather more often than in the feet.

This sort of congenital overgrowth, attended usually with a relatively proportionate increase of the several tissues concerned, is not confined to the hands and feet. It occurs also in the face and other parts. I have recorded¹ the case of a girl aged twelve, in whom there was congenital overgrowth or hypertrophy of the gums on the left side, without and within the alveolar border, which had increased so much as to bulge the cheek and project the lips, and cause such inconvenience as to render an operation for removal of the deformity necessary; the teeth, though in great measure covered by the mass, and the maxillary bone were normal. The lips on the left side were larger and thicker than natural, also the left ala of the nostril, and the left eyelids and eyelashes, and the hair of the eyebrow and that of the forehead, which latter descended lower than on the right side. The pinna of the left ear was a quarter of an inch longer and a little thicker than that of the right ear. The left tonsil and side of the palate and the papillæ on the left side of the tongue also were larger than on the right side. I refer in that paper to other more or less similar cases. In my case the continuance of disproportionate increase was, I believe, confined to the gums. Instances of congenital hypertrophy of the lips have been observed by others;² and the cases of congenital hypertrophy of the tongue, in which all the

¹ *Annals of Surgery*, iii. 1.

² *Ashurst's International Encyclopædia of Surgery*, v. 463.

tissues, some more and some less, are increased, are of the like nature.¹

The real interest of these cases lies in their pathology, and its bearing upon other pathological conditions. They obviously consist in an excess, an abnormally excessive growth of a normal part of the body—an excess not depending upon any superabundance of nutritive supply or any modification of nerve-influence, but upon an excess, a want of due restraint, of that developmental force by which the several organs and structures acquire and maintain their proper dimensions and relations to one another, and by which their relative growth at different periods of life and under different circumstances (as of the genital organs at puberty) is determined. The nature and essence, and habitat or source of this force is a mystery, perhaps past finding out. It seems to be shared, as an inherent quality, by each part and by each tissue in the same manner as by the primitive germ, and as a derivative from it. Each part forms and grows by the *vis inertiae* in itself, though for the supply of the material by means of which it forms and grows it is dependent upon external sources, as the blood in the vessels, and for its co-operation with other parts upon nerve-influence; just as each soldier in a regiment has his own independent force and activity, but depends upon the commissariat for his maintenance, and the trumpet-call for harmonious co-operation with other members of his corps. He may of his own free action take an insubordinate line, to the detriment of his fellow-soldiers and the damage of the service; and he may involve others by his example and influence. The like insubordination to the controlling and harmonising forces of nutrition and growth may be supposed to occur in any tissue or at any period of life. It may continue or it may cease. It may remain localised or it may spread to surrounding parts. It may consist in, or lead to, a mere increase and maintenance of *normal* structure, or it may result in various degenerations or deviations from the normal. It may be attributable to an obvious local cause or stimulus, and may cease with that cause; but in many instances no such cause can be assigned.

Admitting the view thus taken as a working hypothesis, not regarding it as a full explanation, for that is unattainable in our ignorance of the nature of developmental and growing forces, but referring these macrodactyls and other abnormal growths to an over-exercise of that force by which each part attains and maintains its size and structure, we find, I think, a better idea and explanation, or theory, of the nature of tumours than that afforded by the "latent embryonic germ theory" propounded by Cohnheim, and too readily, as I believe, accepted by many modern pathologists. It seems,

¹ Now and then a similar overgrowth commences later in life, as in the case of a woman, aged thirty, mentioned by Cohnheim (*General Pathology*, ii. 750), in whom hypertrophy of both hands and the lower part of the face thus took place. It seems probable, however, that this should be regarded as a case of "acromegaly," which, I may observe, is a morbid condition occurring usually in adults and affecting the system generally, not, like "macroductyly," a localised congenital overgrowth.

indeed, a piece of supererogation thus to increase our difficulties by resorting to this view, which has *two* postulates instead of one : *first*, the presence of the latent germs, of which I need scarcely say there is no evidence ; and *secondly*, the starting of these germs into a mischievous or insubordinate activity without any assignable cause.

Let us trace this simple theory of "overgrowth" or "hyperplasia" which I am advocating, and have for years maintained and taught, as against the "latent germ theory" in its application to various growths.

The congenital MACRODACTYLS and other congenital hypertrophies above described are obviously mere enlargements or overgrowths of normal tissues, of a finger, a toe, a lip, or a tongue, which in some instances proceed indefinitely, in some cease to increase after a time, in some extend to the surrounding tissues, and in some remain limited to the part first affected.

NÆVUS is a similar condition of blood-vessels, commencing usually a little before birth, and spreading for a time, but commonly for a limited time only.

MOLES or MOTHER-MARKS, in which the cutis is thick, and pigmented, sometimes nævoid or tuberculated, and usually with overgrowth of hair, now and then continue to increase after birth, or start an increase at some later period, as in a case I lately saw where the tubercles grew out into masses requiring removal.

The other FETAL TUMOURS, consisting of cysts, *serous* or *dermoid*, of cartilage, bone, fat, or other structures (the so-called "parasites" are probably, for the most part, of this nature), often exhibit, as might be expected at the time of life when development is in high activity, an insubordination of developmental force as well as of growth, which leads to variation, it may be to undue exaltation, of structure, as well to increase of size, as evinced by the presence of cartilage, bone, skin, and even glandular structure. These tumours usually remain localised, and commonly, as exemplified by the supra-orbital dermoids, cease to grow after a time, their developmental and growing tendencies ceasing with the diminishing developmental and growing forces of the body. They are fully as well accounted for by an excessive growth and change of normally existing germs as by the presence of superabundant germs and an excessive growth of them. That such manifestations of variety and exaltation of structure should be observed in the ovary (they are probably congenital or occurring in early life) is in accordance with the marvellous formative properties of the Graafian bodies of that organ when normally acting under the influence of the natural stimulus.

With regard to the extra-uterine growths a WART is a localised enlargement or overgrowth of the papillary tissue of the skin, continuous with the surrounding skin and spreading into it, the overgrowth being commonly excited by some local irritation. POLYPI are of like nature, not spreading so much into the mucous membrane with which they are continuous as growing in the direction of least resistance. The DIFFUSED LIPOMATA of the neck and the DIFFUSED

MYOMATA of the uterus, PERIOSTEAL FIBROIDS, and EPULIS are clearly, like macrodactyls, localised overgrowths of the respective tissues, started into activity by some unknown cause. The continuity of these growths with the tissues in which they are found, and the manner in which they spread into these tissues by exciting the like overgrowth in them, seem sufficient evidence of their nature and derivation from normal structures, and to be incompatible with the idea of their derivation from latent and suddenly active superabundant germs.

The more CIRCUMSCRIBED TUMOURS are but a step removed from these last, in that the insubordination of growth is, and remains, more limited. Moreover, in some of these the limitation is not absolute—that is to say, the growth is not quite confined to the starting-point, but extends to a certain extent in the surrounding tissue. This, at least, we may infer to be the case in many of the subcutaneous lipomata from their lobulated character and the manner in which they are penetrated by fibrous septa passing into them from the skin, and giving the characteristic dimpling or fissuring of the surface. They are most frequent in the persons and parts where the growth of normal fat is greatest, and they sometimes take their start at many points. The MAMMARY ADENOMATA are also good illustrations of localised overgrowth of a normal structure, composed of modified mammary tissue, usually remaining continuous with the mammary gland, and apparently, in some cases, owing their increase partly to an extension to or an involving of it. The tendency to this insubordinate growth may exhibit itself at any part, giving rise to two or three tumours in a mammary gland, to a dozen in a uterus, and to a hundred or more in the subcutaneous fat. They usually present the general structural features of the tissue in which they are found, though in some instances, as by the presence of cartilage in the testicle and the salivary glands, they show developmental variations from the normal connective tissue of the part.

The osseous system is fertile in an interesting and instructive gradation of these more or less insubordinate productions, ranging from the callus, often excessive after fracture, and the osteophytes about joints, ulcers, and necroses through the varieties of scleroses and nodes, to the ossifications into tendons, exostoses, enchondromata, and osteomata. Some of these are the result of an increased supply of blood caused by congestion of blood-vessels from various causes, while others take place without any apparent cause, and can only be ascribed to an overgrowing of the cartilage or bone structure where they spring; and in proportion to their independence of any known cause are they resistant of any known treatment.¹

The MALIGNANT GROWTHS fall into the same category. The insubordinate growth, set agoing often by some continued irritation,

¹ The little pieces of cartilage occasionally found in the shafts of rickety bones, as the remnants from imperfect and irregular ossification at the epiphysial lines, do not really afford any argument in favour of the embryonic germ theory of tumours, forasmuch, as far as I am aware, they do not ever become developed into tumours.

when once begun spreads along the adjacent tissue; and the pertinaciously multiplying germs of the tissue in which they form insinuate themselves into the surrounding structures, reaching the lymph- and blood-streams, and carrying their evil influences wherever they go. This is well shown by the carcinomata, the epithelial growths of which infect the surrounding epithelium, pass into the subjacent tissue, infiltrating it, partly destroying and replacing it, and partly giving rise to a low fibroid hyperplasia of its connective tissue, whereby is formed the areolar network in which the cancer cells and germs lie nested. The functionless included products of these germs, being out of the range of normal metabolism and the natural outlets for the epithelium, die and decompose, and force an abnormal exit through the medium of ulceration or mortification, while the infiltrating and spreading products are carrying the like destructive influence to neighbouring and to distant parts.

Into the primal cause of tumours, that which first excites and gives continuance to the impulses of inordinate growth and assimilative power, we can, as I have already said, no more penetrate than we can into the primal cause and regulation of normal growth and nutrition. The gradations I have mentioned from callus to osteomata, and those between simple warts, warty epitheliomata, and infiltrating epitheliomata, and the known exciting causes of some of these, may help us to approach a somewhat nearer knowledge of the ætiology of the tumours, but a clear conception of it must await a closer insight into the laws of nutrition and growth. I wish here merely to accentuate the view that whatever may be their several exciting causes, and however much they may differ in their characters and progress, macrodactyls and nævi, warts and tumours, simple and malignant, are essentially alike in the feature of being overgrowths of the parts or tissues in which they take their origin.

I can quite agree with Cohnheim that there is "no fundamental difference between foetal and extra-uterine growth," and that the real cause of a tumour may be "sought in a fault or irregularity in the embryonic rudiments." Indeed, some such faults or irregularities, evincing themselves in the course of the developmental progress of those rudiments, or rather of the structures resulting from them in any of the several stages from the foetal to the senile state, may be regarded as the source of a large number of the weaknesses and maladies, tumours among others, which occur at various periods of life. They constitute, indeed, a widely embracing factor in pathology; and the body which is most free from such faults is least prone to disease, and best fitted to hold on through the greatest length of time.

Postscript.—Mr William Anderson, in a valuable paper in *St Thomas's Hospital Reports*, vol. xi., gives a case of giant growth, apparently congenital, of the left lower limb, with tumour formation in connection with the superficial parts, in a woman æt. 25. The growth was progressive, and increased most rapidly after the ordinary body-

growth had almost reached its complete development. Many cases of congenital hypertrophy are referred to, and much information on the subject given.

Addendum.—In Professor Annandale's work on *Diseases of the Fingers and Toes*, Edinburgh, 1865, which he has kindly sent me, cases are given of congenital hypertrophy of the fingers and toes, in some of which the parts were amputated, and the disease was found to consist of a hypertrophy of all the tissues which usually compose the digits.

G. M. H.

March 1892.

Notices of New Books.

- I.—*Il Cervelletto ; nuovi studi di fisiologia normale e pathologica.*
Per LUIGI LUCIANI. Firenze, 1891.
- II.—*Sull'origine e decorso dei peduncoli cerebellari e sui loro rapporti cogli altri centri nervosi.* Per Dr VITT MARCHI. Firenze, 1891.

THESE two works, which are the most recent treatises on the anatomical connections and physiology of the cerebellum, form an important contribution from the modern Italian scientific school. The former gives expression to Luciani's matured views on the subject of cerebellar physiology, and includes the experiments which were recorded by him in the *Prima Memoria* in 1884. The latter records the degenerative changes in the central nervous system of the animals on which partial or complete cerebellar extirpation had been performed.

Luciani's memoir forms a very valuable addition to the physiology of the nervous system, and introduces a new doctrine of the functions of the cerebellum. The author has been very successful, both as to the number of animals (dogs and monkeys) on which he has operated, and in the completeness of the partial and total extirpation of the cerebellum ; his method of operation deserves mention. Narcosis was obtained in dogs by hypodermic injection of morphia and chloral (morphia 2.5 centigram, chloral 1 gram), and in monkeys by chloroform, in addition to morphia. The muscles were separated down the middle line of the neck, and partly detached from the linea semicircularis. An opening was then made with a small trephine in the occipital bone, and enlarged by the bone-forceps. The opening thus made extended from the external occipital protuberance to the foramen magnum, so as to expose the whole region as far as the calamus scriptorius. The dura mater was incised over the middle lobe. *The extirpation of the middle lobe of the cerebellum* is a relatively easy operation. This lobe is separated from the lateral lobes by two antero-posterior incisions. A spoon with a cutting edge is introduced, and the brain matter removed as far as the corpora quadrigemina. When thoroughly extirpated, the floor of the fourth ventricle and the opening of the aqueduct of Sylvius are exposed. To remove *the whole cerebellum* at one sitting, proceed as above described, for the removal of the middle lobe, and then remove the lateral lobes as much as possible *en masse*. The removal of the flocculus, although not impos-

sible, is difficult and uncertain. *One half of the cerebellum* is extirpated by dividing the vermis in the middle line, by means of a Græfe's knife. It is essential that the remaining half be not injured. It is difficult to perform hemi-extirpation of the uvula cerebelli without at the same time injuring the medulla oblongata. Hæmorrhage from the brain is arrested by means of small sponges, soaked in corrosive sublimate (1 in 1000).

The disadvantage of operating on monkeys is that the head requires to be held forward by an assistant. In favour of the use of these animals is the very ready manner in which they are narcotised, and the only slight tendency to epilepsy after the operation. In dogs this tendency is combated by hypodermic injections of chloral. The latter, also, are subject to impulsive movements after the operation, and have sometimes to be artificially fed. In monkeys, on the other hand, the irritative phenomena are less intense and more fleeting.

Having overcome the difficulty of removing the cerebellum, we must next see how best to define the phenomena which result from it. In studying the movement of an animal, several principal factors are distinguished — the energy employed in the contraction of the muscles, the tension or tenacity of the muscles, the manner of effecting the contraction, the form of the movements, their symmetry, and their co-ordination, or the manner of association, and succession of movements.

For estimating the force of muscular contraction, the author has made use of a modified dynamometer. He noticed that when a monkey was raised from the ground by means of a belt round the abdomen, it endeavoured to catch hold of any fixed object below it. He therefore attached the hook of a dynamometer to the animal's girdle-strap, raised it from the ground, and allowed it to approach a wooden cylinder maintained in a vertical position by a heavy base. To this the monkey clung with both its hands, and gradually drew out the dynamometer ring, thus enabling the observer to read on the scale how many kilogrammes it had overcome with the arm muscles. In order to complete and control the observations on cerebellar ataxy, especially as regards the form, symmetry, and co-ordination of movement, he devised a method of tracing the footsteps of dogs on the pavement, by dipping their feet into different-coloured solutions. Throughout the work there are charts, showing the normal impress of dogs' feet when walking and when galloping, and also of those animals, at various periods after the operation, whose cerebellum had been, in whole or in part, removed.

Luciani has studied the nature and origin of the changes consequent on mutilation of the cerebellum under the following headings: phenomena of irritation; effect of division of the cerebellum into two halves; effects of destruction of the middle lobe; effects of incomplete unilateral extirpation; effect of removal of one-half of the cerebellum; effects of complete and incomplete extirpation of the whole cerebellum; effects of extirpation of the cerebellum combined with uni- or bi-lateral destruction of the sigmoid gyrus.

The experiments show that the cerebellum is not an organ inter-

calated among the great paths of the cerebro-spinal system, and as such transmitting voluntary impulses from the cerebrum to the spinal cord, but that it is an appendix, by the side of the cerebro-spinal paths, being essentially an auxiliary or reinforcing organ for the central nervous system, which is the more developed the higher one goes up the vertebrate scale. Complete destruction of this organ does not produce paralysis of any groups of muscles: a proof of this is found when stimulation by electricity of the sensori-motor sphere of the cortex provokes the same reaction as if the cerebellum were untouched.

Of the greatest importance in this relation is the intimate anatomical connection which the cerebellum has with the grey matter of the pons Varolii by its middle peduncles. With this knowledge we cannot but think that the traumatic and inflammatory irritation of the peduncular fibres is transmitted directly to the ganglionic elements of the pons.

There only now remains to briefly consider certain trophic changes. For the first few days after the operation there was noted in some of the animals polyuria, glycosuria, and acetonuria. But apart from these temporary conditions during the course of the ataxy, certain general and local trophic phenomena were observed. Marasmus was occasionally present without any evident cause for its onset. Alopecia, erythema, and eczema were noted in several cases at various periods. Conjunctivitis, keratitis, and otitis were observed on several occasions. These solutions of continuity readily healed under the use of disinfecting lotions. Fatty degeneration of the muscles of the extremities was also seen, associated with increase in the number of the nuclei of the sarcolemma.

The last chapter of Luciani's memoir is devoted to "the first lines of a new doctrine." The results of the researches show that the cerebellum is an organ of bilateral function, but with mainly a direct action, in this way differing from the cerebral hemispheres, which also exert a bilateral action, but mainly crossed. The experiments also indicate that cerebellar influence is not limited to the muscles which regulate the different forms of posture and locomotion, but extends to all the voluntary muscles. They further clearly show that the middle lobe is not of greater functional value than the lateral lobes, and that, as a rule, the different portions of the cerebellum have the same functions, and that the cerebellum is not a collection of centres functionally distinct or different, or that the various segments have an intimate or direct influence over special muscular groups, but that the influence which the cerebellum normally exercises over the system is asthenic, tonic, and static, neuro-muscular action. It is also evident that the cerebellum transmits, by its efferent paths, a trophic action, direct and indirect. The direct is shown in the degenerations and scleroses which follow its ablation, the indirect by the muscular and cutaneous dystrophies which have been recorded. The functional influence, which the cerebellum transmits normally to other nerve centres, is slow, quiet, and continuous. But the experimental, as well as the clinical evidence, shows that in morbid states, both the trophic and functional activities are increased, so as

to produce violent perturbation and disturbance of the sensorial, motor, and trophic functions. The sensorial disturbance consists essentially of vertigo, the motor of those multiform aberrations which produce motor inco-ordination, while the trophic finds expression in polyuria, glycosuria, acetonuria, and rapid decrease in weight. The trophic and functional influences probably represent different aspects of one complete physiological process, of the nature of which we are ignorant.

The functional action of the cerebellum is different from that of the other parts of the nervous system. The effects of cerebellar deficiency have been shown to be asthenic, atonic, and astatic, while those of other centres show complete or incomplete paralysis of motion and sensation. The reason of this is that this organ forms a small, relatively independent system, defect of which does not interrupt centripetal or centrifugal conduction between the cerebrum and the peripheral nervous system. It is to be regarded as a coadjutor or reinforcing organ to the great cerebro-spinal system.

Luciana entrusted the brains and spinal cords of the animals (dogs and monkeys) on which the preceding observations had been made to Marchi, for the purpose of following out the degenerations which resulted from the extirpation of whole or part of the cerebellum. For this purpose Weigert's hæmatoxylon solution, and a method which now is known as Marchi's method, were used. Briefly stated, this consists in hardening the tissue in Müller's fluid. After a short time, pieces the size of 1 cm. are cut, and placed for eight to ten days in a mixture of Müller's fluid (2 parts) and osmic acid (1 part). The tissue is then prepared for the celloidin process. The degenerated tissue is stained black.

1. The degenerations which result from extirpation of one-half of the cerebellum (*e.g.*, right hemi-extirpation):—

(*a*) In the region of the superior peduncles the osmium-bichromate method showed evidence of degeneration in the right superior cerebellar peduncle, and partly also in the left; much degeneration of the left red nucleus, and slightly of the right, while in addition there was evident alteration in the fillet, many of the fibres of the third pair of nerves, the posterior longitudinal bundle, some of the fibres of the pyramidal tracts in the crura cerebri, and degeneration of the right optic tract.

(*b*) In the region of the middle peduncles there was found complete sclerosis of this peduncle on the side of the extirpation, the degeneration passing over the middle line. In addition there was found degeneration of the nerve fibres of the fifth pair on the same side of the fillet, of the posterior longitudinal bundle, and of a small band of fibres which lie posteriorly and externally to the superior peduncles. Sclerosis of the grey matter of the pons (*nuclei pontis*) was also observed.

(*c*) In the region of the inferior cerebellar peduncles the following degenerations were brought out by the osmium-bichromate method: the internal portion of the inferior peduncle, the external portion of

the restiform body, certain of the striæ acusticæ and of the external auditory nucleus, many fibres of the ascending root of the fifth nerve, the fillet, the interolivary layer, and the posterior longitudinal bundle. Some of the fibres of the hypoglossal nerve and of the pyramids were also degenerated. In sections treated by Weigert's method the degeneration is not so diffuse, but there is evidence of degenerative change in the olive of the opposite side, the corpus restiforme of the same side, the direct cerebellar tract, and the fillet.

(*d*) In the spinal cord the author has detected degenerations by the osmium-bichromate method. The Weigert method is not so successful in bringing out this degeneration. The tract in question occupies the antero-lateral region of the cord, one portion being in connection with the anterior part of the direct cerebellar tract, the other in connection with the pyramidal fibres on the same side as the extirpated cerebellar hemisphere. As a result of ablation of the middle lobe of the cerebellum the author found the degeneration in the superior peduncles scarce and limited; but there was much alteration found in the fillet, the posterior longitudinal bundle, and the roots of the third nerves and the fibres of the optic tracts. From this one gathers that the fibres of the superior cerebellar peduncles come mainly from the nucleus dentatus and the cortex of the lateral lobes. All the transverse fibres of the middle peduncles are degenerated. The degeneration in the inferior peduncles are limited to the lateral part of the corpus restiforme. There is also degeneration of the fibres of the corpus trapezoidum, and of the roots of the third, fifth, eighth, and twelfth cranial nerves. In the spinal cord there was sclerosis of the antero-lateral columns.

Marchi summarises his results as follows:—

1. The superior cerebellar peduncles do not completely decussate, for a small band of fibres passes to the optic thalamus on the same side, though the principal mass terminates in the red nucleus of the opposite side.

2. The middle cerebellar peduncles are not merely commissural strands from one hemisphere to the other. Many of the fibres enter the pyramidal bundles and end in the grey matter of the same side, while others pass to the grey matter of the opposite side.

3. The inferior cerebellar peduncles send a tract of fibres to the opposite olive. They are in all likelihood formed of afferent and efferent fibres.

4. The posterior longitudinal bundles and the fillet arise from a common origin in the middle lobe of the cerebellum. They course with the middle peduncles and come into relation with the nuclei of the cranial nerves, the nuclei pontis, the corpora-trigemina, and probably also the corpus-striatum. At the level of the olive the posterior longitudinal bundles fuse with the fillet, and thus form a connection with the antero-lateral regions and the anterior horns of the spinal cord.

5. That the cranial nerves are closely related to the cerebellum through the medium of the fillet and the posterior longitudinal bundles.

6. The origin of the three peduncles is diffused over the cerebellum, but particularly the nucleus dentatus furnishes most of the fibres of the superior, the middle lobe of the middle peduncles.

It is impossible as yet to criticise the results which Marchi has obtained and which are briefly recorded above. The osmium bichromate process of staining which is now known as "Marchi's method" is, as far as my experience goes, open to numerous fallacies. The manifold connections of the cerebellum which Marchi has described will therefore require ample corroboration before they can be finally accepted.

WILLIAM ALDREN TURNER.

Zwölf Vorlesungen ueber den Bau der nervösen centralorgane. By Ludwig Edinger. Third edition. Leipzig: Vogel, 1892.

DR EDINGER'S Lectures on the Central Organs of the Nervous System have been recognised as giving to the student a clear and pleasantly-written résumé of the structure of these organs, based upon their development and comparative anatomy. In his mode of treatment of the subject he has adopted a plan which brings before the student in an intelligible form the principles of construction of both brain and spinal cord, and he has shown their mutual interdependence. In the third edition now before us the author is quite alive to the most recent investigations on the nervous system, and, as far as his space would allow, has embodied their results in his lectures. We would especially call attention to the excellence and educational value of the numerous illustrations with which the book is provided.

Beiträge zur Kenntniss der Lage der weiblichen Beckenorgane, nebst Beschreibung eines frontalen gefrierschnittes des uterus gravidus in situ. By W. Waldeyer. With five plates. Bonn: F. Cohen, 1892.

PROFESSOR WALDEYER has contributed this memoir on the position of the pelvic organs in the female, and has dedicated it to the eminent Professor Von Kölliker as a mark of respect on the attainment by the latter of his medical jubilee. It appears that when the late famous Professor Henle reached the 50th year of his doctorate, Von Kölliker had at that time dedicated to Henle a contribution on a similar subject.

Waldeyer's memoir is characterised by the care and thoroughness which mark all his anatomical work. It consists of two parts. The first is a description of the pelvic viscera of a virgin in her 17th year, whilst the second comprises an account of these organs in a woman æt. 22, five months advanced in her first pregnancy. The plates are very artistically executed.

Ligation of the Great Arteries in Continuity, with Observations on the Nature and Treatment of Aneurism. By Charles A. Ballance, M.B., M.S. Lond., F.R.C.S., Assistant Surgeon to St Thomas's Hospital, and Walter Edwards, M.A., M.C. Cantab., F.R.C.S., Resident Medical Officer, St Thomas's Home. Macmillan & Co., 1891. 8vo, pp. 568.

THE chief purpose in this handsome and abundantly illustrated volume is to prove the safety of the method of ligation of arteries by the approximation of their internal surfaces by ligature, as compared with that more commonly adopted of rupturing the inner and middle coats under the ligation. With this view many experiments were made on the large arteries—20 in sheep, 21 in asses, 30 in horses. In no instance did hæmorrhage occur. In two the arterial coats were found to be ruptured, and in six the vessel was not quite occluded, though in some of these it probably would have become so had longer time been allowed before the animal was killed. The process of occlusion consists in the proliferation of the cells of the intima, whereby its approximated surfaces are united, and by the formation of clot above and below. To ensure that the contact of the surfaces is effected, it is necessary that the ligature should be applied with sufficient tightness, yet not so tight as to rupture the coats of the vessel. This requires some nicety and judgment in manipulation; and in order that the contact be maintained, it is necessary that the ligature should not be too quickly absorbable, and also that it should not be of elastic material. Ox peritoneum, kangaroo tendon, or boiled floss-silk are preferred, and failing these, boiled Chinese twist, chromic catgut, or silkworm gut. The knot most recommended is the "stay-knot," consisting of two ligatures, which should be round and smooth, tied in "reef-knot," each separate in the first loop, then drawn and tied together in the second loop. The method of non-rupture of the vessel-coats was advocated by Scarpa, and followed by Hunter and others; and it is obvious that the dangers incurred by rupturing the inner tunics, and more or less damaging the outer tunic, and the consequent liability of the vessel to give way under the blood-pressure, are thereby avoided. In the case of the larger vessels, where the outer tunic is thin in comparison with the inner, and the resistance offered by it to the blood-pressure is therefore least, the danger of after hæmorrhage is too well known; in some, as the first part of the subclavian and the innominate, it is wellnigh prohibitory of operation; and there can be little doubt that, for these and indeed other large vessels, the risk would be much diminished by the avoidance of a rupture of the arterial coats. The difficulty lies in the correct adjustment of the pressure of the ligature.

Much, but not much new, is given respecting the structure of arteries and the effect of ligatures upon them; and the behaviour of the clot is fully discussed. It is found that very often crevices in its substance, or between it and the vessel-wall, due in great measure to its contraction, frequently permit the blood-stream to find its way

down to the ligatured part, and furnish a source of danger when the coats of the artery have been ruptured. Into the clot, where it is in contact with the vessel-wall, the leucocytes and proliferating cells of the intima find or tunnel their way, this being facilitated by the crevices in the clot, and the proliferating or plasma cells become converted into connective tissue and vessels in the usual way, the leucocytes taking no part in this process. The leucocytes and plasma-cells of the proliferating endothelium find their way also along the trabeculae of the fibrin-network which forms in the clot. The leucocytes are said to be absorbed and digested by the plasma-cells, which also act in a similar manner upon the red blood-cells, or dissolve them by some ferment which they secrete. Ultimately the clot is vascularised by the vacuolation of the columns of plasma-cells, whereby blood-channels are formed. This does not take place before the twentieth day. The amount of artery which becomes thus obliterated by the connective tissue and vascular developments in the clot, resulting from the infiltration of and changes in the plasma-cells, varies greatly even in the same artery, being usually greatest where, as in the superficial femoral and the carotid, the vessel is long, and gives off few branches.

The relative thickness of the different tunics of the larger arteries is given. The conduct and fate of the arteries when tied, as well as of the clot, of the corpuscles, and of the aneurism, are exhaustively gone into. All the museums of London are exhausted for illustration, and much historical information given, the whole forming a very interesting and valuable contribution to anatomical, pathological, and surgical literature, and likely to lead to important improvement in surgical practice.

A Text-Book of Morbid Histology for Students and Practitioners. By Rubert Boyce, M.B., M.R.C.S. London: H. K. Lewis, 1892.

In the work before us, the author has presented to the student and practical pathologist a book of great excellence. The work shows an extensive practical knowledge of Morbid Histology, and is replete with information and comments which are evidence of the author's acquaintance with the literature of the subject. The method adopted throughout is somewhat novel. The author describes in detail in the text a typical microscopic section of a diseased state, and gives a figure in illustration. After treating of histological methods, he proceeds to describe the morbid appearances of Inflammation, the Healing of Wounds, and Repair; he also considers the processes of Degeneration and Tumour formation, and the more important tissue reactions in Mycotic and Zooparasitical diseases. The second portion of the book is devoted to the study of the diseases of the Special Systems. By way of illustration there are 130 coloured photo-micrographs; while not the least valuable portion of the book is a very extensive bibliography.

Das Gliedmassen-skelet der Wirbelthiere mit besonderer Berücksichtigung des Schulter- und Becken-gürtels bei Fischen, Amphibien und Reptilien. By Robert Wiedersheim. Text and Atlas. Jena: Gustav Fischer, 1892.

PROFESSOR WIEDERSHEIM of Freiburg has for a number of years been engaged in the study of the shoulder and pelvic girdles, and has published in the journals of the day a number of descriptive articles on the subject. He has brought into the compass of a volume of 266 pages his more extended researches on this subject, which he has illustrated with forty figures in the text, and an atlas of seventeen plates.

He begins his account of the hind-limb and pelvic-girdle with the arrangements found in the Selachia, and then treats of the corresponding structures in the Dipnoi, Ganoids, Bony Fish, Amphibia, and Reptiles, and concludes with short sections on the pelvis of Birds and Mammals. His observations on the shoulder-girdle embrace a survey of the corresponding classes from the Selachia to the Crocodiles. He analyses his observations with his customary acuteness, and concludes the book with a general summary and statement of the conclusions to which he has arrived.

Human Monstrosities. By Barton Cooke Hirst, M.D., and G. A. Piersol, M.D. Parts I. and II. Philadelphia: Lea Brothers & Co., 1891-92.

It is satisfactory to see that the American publishers of medical and scientific books, as well as those who supply our transatlantic brethren with general literature, are applying themselves to the production of original works, and not limiting themselves, as was at one time almost universally the case, to the reprinting of English text-books, and the translating of treatises written in French and German.

The work now before us is in folio volumes, got up with thick paper, wide margins, beautiful type, and numerous illustrations both in the text and in the form of photo-electrotype plates, and is a veritable *edition de luxe*. The material on which it is based is for the most part contained in the Wistar and Horner Museum of the Medical Department of the University of Pennsylvania; though the figures intercalated in the text are in several instances reproduced from the writings of well-known authors. In their classification the authors adopt that of Geoffroy Saint Hilaire, which they consider to be the most convenient for the physician, though they admit that it is by no means satisfactory from the standpoint of modern science. They discuss the production of malformations in connection with the development of the human em-

bryo, and review the attempts which have been made to produce malformations artificially. They then proceed to consider the various classes of malformations under the following heads:—Hemiterata, Heterotaxis, Hermaphrodites (and under this head they substitute the classification of Klebs for that of G. St Hilaire), and Monsters. Sections on Hemiterata, Heterotaxis, and Hermaphrodites are in part i., but they are disposed of in much too summary a fashion, considering the importance of the subjects falling under those heads. For example, the section on Heterotaxis is limited to fifteen lines, and the whole question of transposition of the viscera is dismissed in two short sentences. The subject of monstrosities is, however, treated in a much more detailed way, and the reader is carried in part ii. as far as the consideration of the malformations of the head.

Biologische Untersuchungen, neue Folge II. and III. By Gustaf Retzius. Stockholm: Samson & Wallin, 1891-92.

ALL anatomists who are acquainted with the large illustrated works by Professor Gustaf Retzius on the connective tissue of the nervous system and on the organ of hearing in Vertebrata, produced either in conjunction with Dr Axel Key, or alone, have become familiarised with treatises which are amongst the most beautiful in typography and illustration of modern works of science. They exhibit also a care and completeness in the investigation of the particular departments of which they treat, which has given them a definite and well-assured place in anatomical literature.

Professor Retzius continues his researches on the nervous system, and under the general title of "*Biologische Untersuchungen*," has produced within three years as many folio volumes. In the first volume, published in 1890, the nervous system of the Crustacea, the nerve cells and caudal heart of *Myxine glutinosa*, the reticulate structure of the human ovum, and the structure of muscular fibre were under consideration. We have recently received vols. ii. and iii. In the second volume the central nervous system of the Annulata is described in a number of species, and two chapters are written on the central nervous system of *Amphioxus* and *Myxine*. In volume iii. the author writes on the nervous system of *Lumbricus*; on the nervous elements of the cerebellum; the mode of ending of olfactory nerves, auditory nerves, and nerves of common sensation and of motion; the nerves of the spleen and kidneys; the ganglion cells of the sympathetic; the endings of nerves in the salivary glands; the bile capillaries of the liver.

In the series of important researches on the nervous system, the author has employed the silver methods of Golgi and Ramón y Cájal, and Ehrlich's method with methylin blue. The three volumes are illustrated by fifty-seven beautifully executed lithographic plates.

Quain's Elements of Anatomy. Edited by E. A. Schäfer and G. D. Thane. Tenth edition. London: Longman, Green & Co., 1890-92.

THE editors of *Quain's Anatomy*, in preparing and issuing the tenth edition of the well-known class-book, are pursuing a different method from what has been the habit in former editions. Instead of publishing the work in two volumes, or in three volumes, as was the case in one if not two of the preceding editions, they are issuing it in parts as soon as each is completed. Thus the parts on Embryology, Histology, Osteology, and that on Arthrology, Myology and Angeiology, have now appeared. Those on Embryology and Histology have been edited by Professor Schäfer, whilst the remainder appear under the editorial charge of Professor Thane. As might naturally have been expected, although all the parts bear evidence of careful revision, those which have come especially under Professor Schäfer's cognisance show a greater amount of change both in the text and figures from the immediately preceding edition. We need say no more than that the tenth edition of "Quain" continues the high standard of excellence which has been gained by its predecessors.

L'Homme dans la Nature. By P. Topinard. Paris: Felix Alcan, 1891.

DR TOPINARD has written for the Scientific International Library a volume on Man's place in Nature. It is a popularly written book, intended to convey to the general reader the present state of the science of Anthropology; the methods of Anthropometry; the characters of the human skull and brain; the bipedal and quadripedal attitudes; the distinctive characters of hands and feet; and the place of Man in zoological classification.

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PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

NOVEMBER 1891.

THE Fifth Annual General Meeting of the Society was held on Monday, November 23, in the Library of St Bartholomew's Hospital Medical School. Present—Sir WM. TURNER (President) in the chair, and fifty-six members and visitors.

The Minutes of the previous Meeting were read and confirmed. The following gentlemen were elected officers for the ensuing year :—*President*—Sir Wm. Turner, F.R.S. *Vice-Presidents*—John Curnow, M.D. ; Alexander Macalister, F.R.S. ; Peter Redfern, M.D. *Treasurer*—G. B. Howes. *Secretaries*—Ambrose Birmingham, M.D. (Ireland) ; J. Yule Mackay, M.D. (Scotland) ; George Henry Makins (England). *Council*—Wm. Anderson, Stanley Boyd, W. H. Bennett, D. J. Cunningham, F.R.S. ; John Cleland, F.R.S. ; Wardrop Griffith, M.D. ; W. P. Herringham, M.D. ; Alexander Hill, M.D. ; Robert Howden, C. B. Lockwood, Clement Lucas, A. M. Paterson, R. W. Reid, Charles Stewart, J. Bland Sutton, Johnson Symington, G. D. Thane, Arthur Thomson, Bertram Windle, Alfred H. Young.

Mr EDWARD FAWCETT, M.B., C.M., was elected a Member of the Society.

The following gentlemen were nominated for election at the next meeting :—T. Manners-Smith, B.A. Cantab, M.R.C.S., Demonstrator of Anatomy at Queen's College, Birmingham, proposed by B. C. A. Windle, Alexander Macalister, Alexander Hill ; and H. B. Robinson, M.D., M.S., London, Demonstrator of Anatomy at St. Thomas's Hospital Medical School, proposed by G. H. Makins, Wm. Anderson, and F. G. Parsons.

The Treasurer's Report, showing a balance of £57, 5s. 2d. in favour of the Society, was received and adopted.

Professor ANDERSON STUART showed a stuffed head of the *Bell Pig* of New South Wales.

Mr C. B. LOCKWOOD showed a *Persistent Müllerian Duct*.

The specimen had been obtained by Dr Ormerod from the body of a *man*, aged 38, who had died of disease of the aortic valves. The following is a brief note of the specimen, which will be supplemented when the examination is completed. Both kidneys and ureters were normal, but in the hilum of the right kidney there was a pyriform structure, which looked like a second pelvis, bending downwards into

a cord, which looked like a second ureter. This resemblance was increased by the fact that the cord ran downwards, parallel to the true ureter, and was like it in size and structure. However, this adventitious cord left the ureter as they approached the iliac fossa, and ran inwards to join the vas deferens as it emerged from the internal abdominal ring. The joining together of the two cords was complete, and the single cord which they formed took the usual course of the vas deferens, to end in the manner usual to that duct. Assuming that the abnormal structure was a persistent Müllerian duct, which had failed to descend with the epididymis and body of the testis, it is evident that the hydatid of Morgagni, which is the remains of the upper end of Müller's duct, ought to have been wanting in the side which the persistent duct occupied, namely, the right. This was so, although the left hydatid of Morgagni was well developed.

The pyriform portion of this persistent Müllerian duct was hollow, and contained a cavity as big as the pelvis of the kidney, but it possessed neither ostium or fimbriæ. From the dilatation a probe could be passed downward almost to the junction with the vas deferens. The utriculus hominis was of the usual size and appearance.

It is proposed to make a further report upon this specimen after a histological examination has been made.

Professor ANDERSON STUART showed a *working Model of a Horizontal Section of the Eye*. He then demonstrated—

1. A *Ring-like Network of Fibrous-looking Tissue in the Ciliary Region of the Vitreous Humour of the Normal Eye*. The tissue is in the form of a membranous network, the dominant lines of which, as seen in sections, are attached to the bounding membrane of the vitreous, just in front of the anterior margin of the true retina. From this attachment they extend backwards and inwards towards the axis of the eye-ball into the vitreous substance. There were shown preparations of the region in the form of a ring, which had been mechanically isolated from the human eye, and sections under the microscope. This account of the intimate structure of the region thus differs greatly from the one usually given.

2. A new preparation of the *Membrane in front of the Vitreous*, lining the fossa patellaris, and forming the posterior wall of the canal of Petit, which is thus a true canal. The membrane is described in the *Proceedings of the Royal Society*, 1891. The preparation shown was in some respects more satisfactory than the earlier ones.

Professor ALEX. MACALISTER showed a series of abnormalities, obtained from the anatomical department at Cambridge.

Professor G. B. HOWES exhibited a *Rabbit's Backbone having a free Lumbar Rib*, and made the following remarks thereon. As the Rabbit is one of those quadrupedal mammals having the same cervico-thoracic vertebral formula as man, the presence in it of a free rib in articulation upon the first lumbar vertebra is of general interest, in view of Rosenberg's discovery¹ that a similar rib is

¹ *Morph. Jahrb.*, Bd. i. pp. 86, et seq.

represented in cartilage in the early human foetus. In the specimen exhibited, the free rib was present only on the left side (*r*, fig. 1); it measured $\frac{1}{2}$ of an inch in length, and was diverted backwards and downwards; a definite facet for its articulation was developed upon the antero-lateral border of its related vertebra, the lower lamina of the transverse process of which was reduced. It entered into the composition of the thoracic wall, and had, in all respects, the characteristic relationships of a normal posterior thoracic rib. The lower lamina of the transverse process of the opposite side (fig. 1) was fully developed but abnormal, in respect to the prolongation of its posterior border into an immovable spur of bone, having a similar disposition to the free lumbar rib. On comparison with the

SPIV

SPVII

PLATE IV. VERTEBRÆ.

III.

i., the last thoracic and two first lumbar vertebræ, ventral aspect; ii., the thoracic vertebræ, numbering six to ten, ventral aspect; iii., the thoracic vertebræ, numbering four to ten, dorsal aspect; iv., the thoracic vertebræ, numbering seven to ten, left lateral aspect; *c*, centrum; *fc*, capitular facet; *pr*, transverse process; *r*, lumbar rib. All natural size.

normal vertebra, this spur might at first sight appear to represent the epiphysial outer extremity of the transverse process (which is variable in its extent and mode of ossification), and to suggest that that structure might represent a vestigial rib. Further comparison with the posterior thoracic vertebral segments was, however, fatal to any such supposition, and it showed, unmistakably, that while the spur in question undoubtedly represented a lumbar rib, its ankylosis with the adjacent transverse process was the direct outcome of the non-reduction of that structure. It had, indeed, suffered (except for its greater increase in length) substantially that change described by Rosenberg¹ as normal for the human subject.

The special interest of the specimen lay, however, in the rationale of existence of the free lumbar rib itself. The animal from which it was obtained was, so far as could be determined, normal and healthy, except for an abnormality involving the 8th and 9th thoracic

¹ For a discussion, with extension, of this author's conclusions, see *Birmingham Jour. Anat. and Phys.*, vol. xxv. p. 526.

vertebræ (figs. ii., iii., iv.). The ossific halves of the centre of these had failed to unite in the customary manner, an oblique fusion having been established between the right half of the 8th and the left half of the 9th. On examining the specimen from beneath (fig. ii.), the free half of the 9th vertebra was seen to have remained undisturbed, while that of the 8th had been carried forwards, with marked indications of atrophy, as the result of domination by forward extension of the ankylosed (right) half of the 9th. There could be no doubt that the condition of the parts was directly due to the failure of the two halves of the centre to unite; and the specimen lent considerable support to the belief in the morphologically double nature of the vertebral centrum, originally advanced by Johannes Müller,¹ Von Baer, and Rathke,² and recently substantiated by Rosenberg³ and Foriep⁴ in their discovery of the paired nature of its 'Anlage.'⁵ The total area of the body occupied by the metamorphosed 8th and 9th vertebræ with their associated skeletal and muscular apparatus was little, if at all, in excess of that normal to a single posterior thoracic segment; and, as the joint result of this retardation in growth and the deformity of the parts related to the two vertebral segments named, the thoracic box of the animal must have been placed at a mechanical disadvantage. When this is borne in mind, the facts concerning the free lumbar rib already alluded to fully justify the conclusion that nature had, so to speak, fallen back upon that structure in seeking to make good the deficiency, pretty much as she calls in the aid of the outstanding episkeletal muscles during forced respiration. Professor Howes had examined some scores of Rabbits' skeletons, and had found only one (in addition to that exhibited) possessed of undoubted lumbar ribs. They were borne upon the 1st lumbar vertebra; and, inasmuch as the thoracic skeleton of the animal possessed of them was deformed, he inclined to the belief that these observations justify us in arguing, by analogy, that the clue to the appearance of a free lumbar rib in a mammal having an otherwise normal backbone and costal skeleton is to be sought in a functional inefficiency of some one or more of the non-skeletal parts active during normal respiration.

On viewing the abnormal parts of the specimen exhibited from the dorsal and lateral aspects (figs. 3 and 4), the left arch of the right vertebra was seen to have alone approximated towards the normal proportions. In attempting to realise them it had become ankylosed to the corresponding arch behind. The remaining portions of the arches of the two vertebræ involved had undergone a retardation in growth, and one conspicuous result of the inequality of this had been the forcible divarication of the two halves of the eighth neural

¹ *Handbook of Physiol.*, English translation, p. 1613.

² Cf. Robin, *Journ. d. l'Anat. et Phys.*, t. 1, 1864, p. 276.

³ *Loc. cit.*, p. 131.

⁴ *Archiv f. Anat. et Phys.*, *Anat. Abth.* 1886, pp. 125-127.

⁵ For interesting information bearing upon both the morphological and pathological aspects of this subject see (α) Sir Geo. Humphry's work, *The Human Skeleton*, pp. 123, 124; (β) Willett and Walsham in *Trans. Medico-Chirurg. Soc.*, vol. lxiii. pp. 257-301; and (γ) Bland Sutton in these *Proceedings* for April 1890, and *Trans. Path. Soc.*, vol. xli. p. 341.

spine. The neural arches of the 9th vertebra had ankylosed while the halves of its spine were in the very act of becoming separated. The seven anterior thoracic spines bore marked traces of the effects of the disruption in the form of a fenestration (fig. 3), which, while testifying to the morphologically paired nature of the spines themselves, showed the mechanical effects of the abnormality to have been transmitted from segment to segment in a manner as obvious as it was suggestive.

Professor ANDERSON STUART commented upon the *Tubercle situated on the Posterior Border of the Great Trochanter of the Human Femur* ("Tubercle of the Quadratus," Thane), pointing out that it corresponded to the line of junction of the epiphysis of the great trochanter with the shaft.

Messrs W. G. LEE and C. P. WHITE showed a body containing the following abnormalities:—*a, accessory digastric.*

On both sides there is a slip of muscle arising by muscular and tendinous fibres from the posterior belly of the digastric muscle just as it is becoming tendinous; the slip passes downwards and forwards, and is inserted into the fascia connecting the hyoid bone with the digastric, and also by a distinct tendon into the anterior belly of the digastric (deep surface of). Its nerve comes from the hypoglossal close to the nerve to the thyro-hyoid. On the right side this nerve-branch was examined microscopically, and found to be true nerve. The innervation of the digastric and stylo-hyoid is normal. The artery to the slip comes from the hyoid branch of the lingual. On the right side the stylo-hyoid does not split, but passes completely in front of the digastric; on the left side it is normal.

b, In the same body the *levator glandulæ thyroideæ* is segmented off from the crico-thyroid muscle, and not from the infra-hyoid muscles as usually described. It arises from the lower border of the thyroid, and inferior tubercle of the oblique line on the right side, crosses the cricoid cartilage obliquely, and is attached to the sheath of the left lobe of the thyroid body. Its nerve comes from the external laryngeal. The pyramid is present on the right side.

Dr HERRINGHAM showed an *abnormality of the first part of the small intestine*. The vertical part of the duodenum ended in the transverse at the normal place on the right side of the 3rd lumbar vertebra. The transverse part ran almost horizontally across the spine to the left side of the same vertebra. It here turned downwards, passed behind the descending layer of the transverse mesocolon, and ended in the jejunum. The first 9 inches of the jejunum, instead of having a free mesentery, lay wholly behind the peritoneum. For the first $1\frac{1}{2}$ inch it ran downwards upon the side of the body of the 4th lumbar vertebra; for the next 5 inches it ran obliquely downwards and to the right, covering the disc between the 4th and 5th lumbar vertebræ. It turned on the outer border of the psoas, and ran upwards to the level of the transverse mesocolon, behind which it lay in contact with the duodenum. It then passed forwards, and received a free mesentery.

THE SECOND ANNUAL REPORT OF THE COLLECTIVE INVESTIGATION COMMITTEE¹ was laid upon the table. Professor THANE proposed a vote of thanks to Mr Arthur Thomson for the labour and care he had bestowed upon the Report. He was glad to find that the results confirmed current views, showing, for instance, that the most usual arrangements were those which, in the last edition of *Quain's Anatomy*, he had already chosen for types. Professor ALEX. MACALISTER seconded the vote of thanks, and brought forward the following Appendix :—

Appendix to the Second Annual Report of the Collective Investigation Committee.

Owing to the exceptional disturbance in our Anatomical Department, due to our removal to the New Buildings in Cambridge and to inadvertence on the part of some of my subordinates, the notes of the observations were so very irregularly kept that I have been unable to reconstruct tables comparable with those sent in from the other schools.

In regard to the first, or the branches of the thyroid axis, I find notes of thirty-nine bodies, which in percentage so substantially agree with those in the Report that it is not necessary to add them. There were, however, two remarkable cases worthy of note. In one instance the cervicalis ascendens artery was very large, and, ascending to the back of the scalp, replaced the third stage of the occipital artery, which was otherwise non-existent.

In another instance, a separate inferior thyroid artery arose from the right subclavian before the origin of the right vertebral. In four instances a thyroidea-ima coexisted with the normal inferior thyroid—a condition which seems unrepresented in the returns.

The only condition which was carefully sought for, and of which the notes have been kept, are those regarding the arrangement of the ileum and cæcum and the occurrence of a diverticulum. I have now notes of 395 bodies in this respect, and have found three examples in this number, making its percentage of occurrence .76.

Several specimens from St Bartholomew's Hospital Museum were on view before and after the meeting.

The meeting then adjourned.

The Committee of Management desire to point out, apropos of the balance accruing from the recovery of subscriptions in arrear, that the Society is now in a position to more fully illustrate its proceedings, and also to perform some additional service to its members. A movement is on foot towards assisting in the preparation of an analytical index to the back numbers of the *Journal of Anatomy and Physiology*, and the Committee hope soon to be able to report more fully upon the same.

¹ See *Jour. of Anat. and Phys.*, July 1891.

PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

FEBRUARY 1892.

THE Second Quarterly Meeting of the Society for the current year was held on Monday, February 22nd, in the Library of St Thomas's Hospital Medical School. Present—Sir WILLIAM TURNER (President) in the chair, and fifty-one members and visitors.

Mr T. MANNERS-SMITH, B.A., M.R.C.S., and Mr H. B. ROBINSON, M.D., M.S., were elected Members of the Society.

The following gentlemen were nominated for election at the next meeting:—T. H. Openshaw, M.B., B.S., Durham, F.R.C.S., proposed by A. Thomson, C. B. Lockwood, and J. Black. E. Cotterell, F.R.C.S., proposed by G. D. Thane, Bilton Pollard, and Percy Flemming. A. R. Kanthack, M.A. Lond., M.R.C.P., F.R.C.S., proposed by W. Bruce Clarke, W. P. Herringham, and H. D. Rolleston.

Sir WILLIAM TURNER gave an account of the *Cerebral Hemispheres* of *Ornithorhynchus paradoxus*, and compared them with those of *Echidna hystrix*. The paper is printed *in extenso* in the *Journal of Anatomy and Physiology*, April 1891.

Dr ALEXANDER HILL had listened with the greatest interest to Sir William Turner's description of the brain of *Ornithorhynchus paradoxus*. He (Dr Hill) had himself studied the brain at various times for some years, although he found it in certain respects so paradoxical that he had abstained from publishing his results, in the hope that he might in the meantime discover the explanation of its singular departures from the ordinary mammalian type.

The brain in Dr Hill's possession would appear to have been taken from a much older specimen than that of Sir William Turner. Dr Hill illustrated the points in which he did not agree with Sir William Turner, by a series of photographs of his specimen.

The hemisphere is very much expanded and thin from above downwards. It completely covers the optic lobes, and hides also a large part of the cerebellum. It shows a well-marked division into frontal, temporo-sphenoidal, and occipital lobes, but no convolutions or fissures so far as Dr Hill could see, with the exception of the rhinal and hippocampal fissures.

The olfactory bulb is a good deal larger than figured in Sir William Turner's diagram. Its connection with the cerebrum is by means of an olfactory peduncle, which is cut off from the under surface of the hemisphere by a deep fissure on either side. The two fissures incline towards one another, leaving but a narrow isthmus between the hemisphere and the olfactory peduncle. The olfactory peduncle is applied at its root to the inner surface of the temporo-sphenoidal lobe, upon which it fades away.

The cornu ammonis has a remarkable course, being continued forwards above the commissures and above the velum interpositum almost to the front of the brain. The fissure which Sir William Turner suggested might possibly be the splenial fissure is a fissure which lies above the cornu ammonis (being really the homologue of the hippocampal fissure); it is continued forwards to the frontal extremity of the brain.

The outer surface of the brain is marked by deep furrows for arteries, but by no fissures. The furrow for the middle cerebral artery occupies the ordinary situation of the fissure of Sylvius.

Dr DAVID HEPBURN communicated the following Note on *a large defect in the Capsule of the Shoulder Joint*.

The comparative rarity of the following appearances warrants their being recorded somewhat in detail, although the condition is probably pathological.

During the dissection of a right upper limb in an adult male, when the deltoid muscle was detached from its origin and turned downwards, the subdeltoid bursa attracted attention by reason of its large size. It extended as far back as the upper border of the insertion of the teres minor, and as far forwards as the insertion of the subscapularis.

Continuing the dissection, the acromion process was sawn through near its junction with the spine of the scapula and turned outwards, when the continuity of the subdeltoid bursa with the subacromial bursa was seen.

On opening the bursa its cavity was found to communicate directly with the interior of the shoulder joint through an aperture of large size. Careful examination of the capsule of the shoulder joint showed that its attachments were normal, except on the subacromial or superior aspect, where the capsule presented an arcuate free border. The anterior extremity of this border was attached to the upper part of the lesser tuberosity of the humerus: the posterior extremity was attached to the humerus immediately above the insertion of the teres minor muscle, external to the articular cartilage on the head of the humerus. The distance between the anterior and posterior extremities of the arcuate free border was *two and a half inches*. Along the entire length of this arcuated border, the cavity of the shoulder joint was quite open, and communicated with the subacromial and subdeltoid bursa, which thus became a direct extension of the joint-cavity. The cartilage was present on a large area of the head of the humerus, but from the bicipital groove of the humerus

backwards to the insertion of the *teres minor*, a porcellaneous deposit had replaced the cartilage and filled up the groove of the anatomical neck, and had modified the appearance of the great tuberosity. The inferior surface of the acromion process was also smooth and somewhat hollowed to accommodate the part of the humerus just described, and on this surface there were also patches of porcellaneous material. The part of the acromion process with which the humerus articulated did not appear to be covered by synovial membrane.

The acromion process itself next attracted attention. It consisted of two parts, an external and an internal, the division extending across into the acromio-clavicular joint, and strong ligamentous bands connected the two segments.

The external portion articulated with the clavicle on its inner border, and with the humerus on its under surface. Moreover, it was joined to the internal portion by an arthrodial articulation, the cavity of which opened into the acromio-clavicular joint.

The subacromial extension of the synovial lining of the shoulder joint did not extend over the inferior aspect of this articulation.

The *supraspinatus* muscle was inserted into the upper surface of the arcuate portion of the capsule, and not into the humerus.

The *infraspinatus* muscle was partly inserted into the posterior surface of the arcuate arrangement, and partly into the humerus immediately above the *teres minor*, by a small tendon which pierced the capsule. The *teres minor* muscle was inserted into its usual place on the posterior aspect of the great tuberosity of the humerus.

The *subscapularis* muscle had the usual insertion, subjacent to which there was a bursa communicating with the interior of the shoulder joint.

The long head of the *biceps* had its usual disposition, but the bicipital groove was prolonged above the articular surface of the head of the humerus, which was also grooved by the long tendon.

On the superior aspect of the humerus there was no trace of an anatomical neck, and the convexity of the articular surface was continued without interruption over the upper part of the bone. In this position the subdeltoid bursa gave the limit of the joint-cavity, and it was at a distance of one inch and a quarter from the margin of the articular cartilage.

The glenoid cavity did not present any deviation from normal appearances. The gleno-humeral ligament was chiefly under cover of the posterior part of the arcuate free border of the capsular ligament. It extended from the upper part of the capsular ligament to the head of the humerus immediately internal to the highest point of the insertion of *teres minor*. The anterior border of this ligament was free, but its posterior border remained attached to the capsule. The small slip of the insertion of *infraspinatus* which was directly inserted into the humerus pierced the capsule superficial to the gleno-humeral ligament.

The synovial membrane was everywhere smooth and glistening, but in the subacromial region it presented several fringes.

The articulation between the outer and inner portions of the

acromion process corresponded to the position of the plate of cartilage between its two centres of ossification. The margins of the cavity were prominent, and they were joined by fibrous bands, except on the inner side, where this joint-cavity opened into that of the acromio-clavicular articulation.

After these observations were made it was recalled that in the earlier stage of the dissection the clavicle was seen to have been broken internal to the conoid ligament. Union between the fragments had taken place, and the displacement was slight.

A closely corresponding condition was found in the opposite shoulder joint, but the clavicle had not suffered fracture, nor did the acromion process present a division into two parts. The glenoid ligament at one part was deformed by ossific deposit.

The presence of practically the same condition of the shoulder joint on the two sides of the body eliminates the possibility of its having been produced by violence. Probably the force which produced fracture of the clavicle also led to diastesis of the acromion process, and the subsequent formation of a false articular cavity.

The appearances in the two shoulder joints are doubtless the result of pathological processes. The large size of the subacromial bursa; the separation of the capsular ligament from the head of the humerus; the rounded appearance of the head of the humerus, with the deposit of porcellaneous material; the alteration of the outline of the articular cartilage, and the formation of an ossific plate in the glenoid ligament, all point to a condition of *osteo-arthritis* rather than to Charcot's disease of joints.

On the other hand, under the term *osteo-arthritis*, Mansell Moullin, in his text-book of surgery, gives a figure and a summary of appearances which in their main features practically correspond with those recorded in connection with the present specimens.

A discussion followed, in which Sir W. Turner, Professor Thane, Professor Anderson, Professor Curnow, Professor Howes, and Mr Makins took part, the general opinion being that the appearances indicated pathological changes.

Mr F. G. PARSONS demonstrated *some points in the Myology of Rodents*.

(a) *Relation of the Pectoral Muscles to the Panniculus Carnosus.*

In Rodents the panniculus carnosus divides into two layers over the ventral surface of the abdomen, a superficial and a deep. The superficial layer is, as a rule, not very well marked, but is perhaps best seen in the porcupine and guinea-pig: the fibres run forwards and inwards entirely superficial to the pectoral, from which they are not separated by any fascia. The fibres are lost on the surface of the pectoral, but are on the same plane as the platysma, which covers the anterior part of that muscle.

The pectoral muscles in Rodents consist of a sternal and an abdominal portion, the latter rising from the linea alba for a variable distance, the abdominal fibres pass to be inserted deep to the sternal, and some of the highest reach the coracoid process and shoulder capsule, and are

looked upon as the pectoralis minor. The deep fibres of the panniculus are much more strongly marked than the superficial ones: they pass in the same direction forwards and inwards, but are deep to the pectorals, and are inserted into the cartilages of the posterior true ribs close to the sternum and into the linea alba. The most anterior fibres, however, of the deep part arch over the floor of the axilla, and

FIG. 1.—Dissection of Guinea-Pig, showing Panniculus.

pass between the sternal and abdominal fibres of the pectoral, to be inserted deep to the former.

Over the dorsum both layers of the panniculus fuse into one, covering the trapezius and latissimus dorsi.

The nervous supply of both layers of the ventral portion of the panniculus is a large nerve which comes off from the most posterior cord of the plexus, the cord that corresponds to the internal of

human anatomy : this nerve, which may be regarded as a large internal anterior thoracic, runs backwards deep to the deep layer of the panniculus, supplying both it and the abdominal and posterior sternal fibres of the pectoral. The lateral part of the panniculus seems to be supplied by the lateral cutaneous branches of the intercostal nerves, but it is difficult to be sure whether they actually supply the muscle, or only pierce it on their way to the skin.

The fact of the abdominal and posterior sternal fibres of the pectoral being sandwiched in between two layers of the panniculus, and having a bundle of fibres of that muscle passing between the sternal and abdominal parts of it, seems difficult to explain, except by regarding the posterior fibres of the pectoralis as part of the panniculus which

FIG. 2.—Dissection of Agouti, with superficial portion of Panniculus removed.

has acquired bony attachments and become greatly developed owing to the value of the direction of its fibres in moving the humerus.

This view is borne out by the nerve-supply. Again, if the pectoral or part of it could be regarded as panniculus, the origin of the sternalis would be less obscure ; and as the ventral part of the panniculus is supplied by the internal anterior thoracic, one would expect the sternalis to be supplied by that nerve, whether it be regarded as a part of the superficial panniculus or of the pectoral.

The fibres of the deep layer of the panniculus which run across the

axilla to between the sternal and abdominal parts of the pectoral are probably represented in Man by the axillary arches or achselbogen, and as they come off from the antero lateral part of the panniculus, their nerve-supply would be either internal anterior thoracic, or a lateral cutaneous branch such as the intercosto-humeral.

(b) *On the Adductor Magnus in the Agouti*.—In the Agouti the adductor magnus is inserted into the posterior border of the femur, but is not continued to the condyle, nor is it pierced by the femoral artery, which is altogether in front of it.

A well-marked muscular slip from the semimembranosus, which separates from that muscle soon after it arises, is inserted just above the internal condyle, and the artery passes between it and the adductor magnus.

The slip is supplied by the great sciatic, while the adductor magnus is supplied only by the obturator. This arrangement in the Agouti bears out the statement that part of the adductor magnus in Man is derived from the ham-string muscles.

(c) *Double Rectus Capitis Posticus Major*.—This muscle I have found divided into two distinct slips on three occasions in the guinea-pig, but in no other rodent: one of these slips was superficial and the other deep, and both had the usual attachments.

The subject was discussed by Sir W. Turner, Messrs Thomson, Curnow, and Thane.

Mr F. C. ABBOTT showed the following specimens:—

(a) *Specimen of Right Aortic Arch*, from a dissecting-room subject.

The arch passes first upwards and to the right, then backwards and to the left, and then directly to the left in front of the spine, before it turns downwards at the descending arch, which together with the descending thoracic aorta is in the usual position met with in the case of a left arch.

The transverse arch thus forms a curve with the concavity forwards, in which lie the trachea and œsophagus, the highest portion of the arch reaching the level of the lower border of the second d. v.

The order of the vessels arising from the arch is left carotid, right carotid, right vertebral, right subclavian, and left subclavian.

The left carotid arises from the front of the ascending arch, passing obliquely upwards and to the left in front of the trachea, which it crosses at the level of the 1st and 2nd d. v.

The right carotid arises above this from the front of the arch, at the junction of the ascending and transverse portions, passing up in front of the vertebral and subclavian.

The right vertebral arises from the upper border of the transverse arch, close to but separate from the right subclavian, the front of which it crosses, to enter the transverse process of the 5th c. v.

The right subclavian arises from the upper border of the arch, slightly to the right of the mid-line, and turns outwards behind the vertebral, giving off the superior intercostal as its first branch.

Finally, the left subclavian arises from the upper part of a pouch which is present at the front of the arch at the junction of the

transverse and descending portions, and which is joined below by the ductus arteriosus, which is large and patent in the outer part of its

FIG. 3.—Diagram of the Right Aortic Arch.

a. Left Carotid.	f. Oesophagus.
b. Right Carotid.	g. Ductus Arteriosus.
c. Right Vertebral.	h. Vagus.
d. Right Subclavian.	k. Recurrent Laryngeal.
e. Left Subclavian.	

course, but obliterated at its origin, which is situated exactly at the bifurcation of the pulmonary artery.

The pouch-like dilatation represents the posterior root of the 4th left aortic arch, and is crossed by the left vagus, which gives off the recurrent laryngeal beneath the ductus arteriosus, to pass up between the trachea and œsophagus.

The right vagus had unfortunately been cut away.

The left vertebral is given off from the subclavian in the usual position, and enters the 6th c. v.

Though many cases of right aortic arch have been recorded with the order of the four large vessels the same as in the specimen, there is only one other on record in which the right vertebral also came separately from the arch.¹

(b) *Specimen of Left Aortic Arch, with abnormal arrangement of the Branches.*

The arch lies in the usual position, but is somewhat low, the highest point being on the level of the upper part of the 4th d. v. Arising from it exactly in the mid-plane is a short common trunk, which divides after a course of $\frac{1}{2}$ an inch into the two common carotids. From the back of the right common carotid, about 1 inch from its origin, arises the right vertebral, which passes up to enter the transverse process of the 5th c. v.

Next from the arch arises the left vertebral, also entering the 5th c. v.; close to this, the left subclavian; and lastly, from the back of the arch, the right subclavian, which proceeds outwards behind the trachea and œsophagus to its usual position.

This specimen is almost exactly similar to one shown by Mr Gordon Brodie before the Society in November 1888.

(c) *Specimen of Pulmonary Valve with 4 Segments.*

In this heart the only abnormality is in the pulmonary artery, the valve of which presents 4 segments. Three of these segments are of equal size, but the 4th is distinctly smaller, and presents a smaller pouch behind it. This segment is attached to that part of the wall of the artery which is developed from the septum, and not, as is usually the case, to the external part of the wall.

This specimen is therefore in opposition to the view that the extra segment is developed from the anterior or external cushion of the four from which both the pulmonary and aortic valve segments are developed.

Messrs STANLEY BOYD, BLACK, and THANE made some remarks.

Dr HOWDEN exhibited a *heart with several developmental anomalies.*

Professor SHERRINGTON gave a demonstration of the *sensory nerve supply of the hind limb of Macacus rhesus*, illustrated by lantern slides.

The meeting then adjourned.

¹ By Otto in 1835. Henle, b. iii. p. 226.

PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND.

MAY 1892.

THE Third Quarterly Meeting of the Session was held on May 23 at King's College, London, the President, Sir William Turner, in the chair. Present—Twenty-seven members and visitors.

The following gentlemen were elected members of the Society:—T. H. Openshaw, M.B., M.S., F.R.C.S., Demonstrator of Anatomy at the London Hospital; E. Cotterell, F.R.C.S., Assistant Demonstrator of Anatomy at University College, London; A. A. Kanthack, M.B., M.R.C.P., F.R.C.S., John Lucas Walker Student of Pathology at Cambridge.

It was resolved that the next meeting of the Society be held in Edinburgh on Tuesday, August 2, one day prior to the meeting of the British Association for the Advancement of Science, in that city.

Mr J. E. LANE exhibited a sketch of the *right subclavian artery*, running an abnormal course along with the vein, anterior to the *scalenus anticus*.

Mr BLAND SUTTON showed, under the microscope, *sections from the growing antler of a stag (Cervus elaphus)*, which demonstrated that the superficial layer of the velvet is skin, and that the hairs which grow from it are furnished with sebaceous glands. Some of the glands are of large size.

This is of some interest, because cysts similar to wens have been found on deers' antlers.

The PRESIDENT remarked that many years ago he had become possessed of the head of a roe-deer presenting striking peculiarities. The horns were clothed with a thick, greasy, folded integument, the furrows of which were filled with a collection of sebaceous matter. The horns were remarkably hypertrophied, and gave rise to numerous dendritic growths of bone. He had seen a photograph of a similar head at Heidelberg. He had been unable to ascertain whether the head had belonged to an animal which had been castrated, or in which

the testis had been injured. In the light of Mr Sutton's communication, he would be disposed to consider the abundant fatty matter occupying the furrows between the skin-folds as due to the secretion

FIG. 1.—A section of "velvet" from a stag's antler (*Cervus elaphus*) to show the sebaceous glands.

of the sebaceous glands, which had persisted along with the tegumentary covering of the antlers.

Mr BLAND SUTTON read the following paper *On an Occasional Articulation between the Cuboid and the Head of the Astragalus*:—

About a year ago, having occasion to look carefully into the articulations of the tarsal bones, I came across a skeleton in which the cuboid articulated with the head of the astragalus; on investigating the matter, I find that this is by no means very rare.

Jutting from the inferior internal angle of the posterior surface of the cuboid, there is a process (sometimes called the calcaneal process of the cuboid) which projects beneath the sustentaculum tali. This process occasionally terminates in a rounded facet, and comes into contact with the under surface of the head of the astragalus.

This additional facet on the astragalus is situated to the outer side of that for the spring ligament, and its presence modifies the outline of the cartilage-covered area of the head of this bone, not only by making it more extensive, but by filling up the rectangular fossa which usually exists in the angle formed by the facets for the sustentaculum and the spring ligament. I have been unable to make out that this articulation depends on occupation, or upon any malformation of the foot or leg. In the first example in which I detected the condition, the variation was present on both sides, and as the complete skeleton was at my disposal it enables me to state that the

remaining elements of the skeleton were natural in every way. An examination of the foot, which Professor Stewart has been good enough to accept for preservation in the Museum of the Royal College of Surgeons as a type specimen of this variation, shows that the remaining elements present nothing unusual.

Professor THANE had seen a tarsus in which this articulation was present; and Professor MACALISTER had seen two specimens in the

		For scaphoid.
		For spring ligament.
	CUBOID	For cuboid.
For calcaneum.		For sustentaculum.
For astragalus.		
		For calcaneum.

dissecting-room at Cambridge. He was disposed to consider the condition a rare one, as he had not discovered a single instance among the numerous skeletons annually procured for distribution among the students, which he had carefully looked over.

Dr ALFRED HUGHES showed a specimen of an *Unusual form of Abnormal Obturator Artery arising from the Profunda Femoris along with the deep Epigastric Artery*. This artery arose in Scarpa's triangle, passed obliquely upwards into the abdomen, in front of the crural canal, then dipping behind the pubes to reach the obturator foramen. As the artery passed into the abdomen, it lay just in front of a point which would be occupied by the neck of a femoral hernia, had such a condition existed.

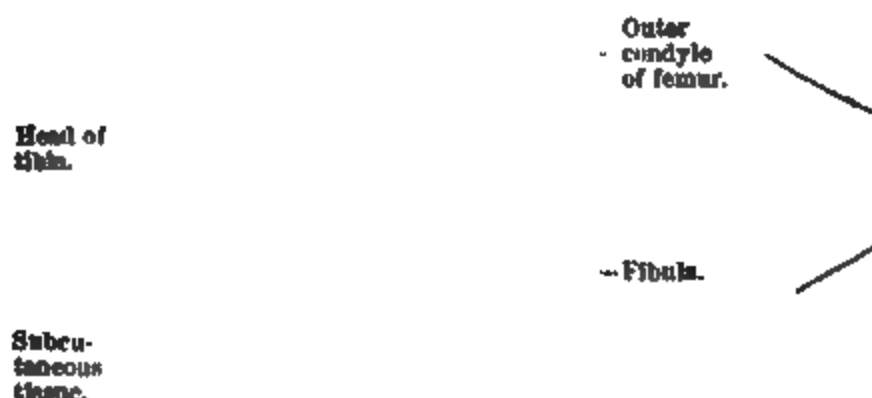
Dr Hughes showed how this specimen differed very markedly from the usual forms of abnormal obturator artery, and that the condition must be very rare, as he had failed to find a similar case recorded. The only specimen presenting any great similarity to this was described in Green's *Varieties in the Arterial System*, 1830, where reference is made to a cast of a specimen in Dr Macartney's museum, in which the normal obturator artery was absent, but in which branches ascended from the profunda artery towards the obturator foramen. Dr Hughes pointed out that, as these vessels did not enter

the abdomen, they differed very markedly from the abnormal vessels shown by him.

Professor MACALISTER stated the cast referred to by Dr Hughes is now unfortunately missing.

Professor CURNOW mentioned that the arrangement shown in this specimen must be very rare. In Prof. Wood's book on Hernia a case is described in which the obturator artery sprang from the internal circumflex of the profunda femoris. Prof. Thane referred to an instance of origin from the internal circumflex noted by Mr Arthur Thomson.

Mr A. S. GRÜNBAUM communicated a note on the *Embryonic Relation of the Fibula to the Femur*. It has been stated by Leboucq and by Bernays that, at an early stage of development in the human subject, the fibula, as well as the tibia, touches the femur; and Gegenbaur mentions the same thing in the description of the fibula in his *Anatomie des Menschen*. This is certainly not the case from



Antero-posterior sections of knee-joint.

(a) Through knee-joint and middle of fibula.

(b) Through knee-joint and outer edge of fibula.

the sixth week onwards, and before that time it is impossible to differentiate the embryonic tissue and say which portion is going to become fibula and which femur. The two figures show the state of things in the seventh and ninth week respectively, from which it appears that the fibula is actually further away from the femur at the earlier date. Morphologically one would anticipate a contact between the two bones; as a matter of fact, it appears not to be the case.

Professor W. ANDERSON read a paper on *The Delimitation of the Regions of the Abdomen*, which will be found *in extenso* in the body of the *Journal of Anatomy and Physiology*, p. 543.

A discussion followed, in which the President, Messrs Macalister, Thane, Symington, Clement Lucas, Curnow, and Bland Sutton took part.

At the suggestion of the President the subject was referred to a Committee, to consist of Prof. Anderson, Prof. Cunningham, Prof. Macalister, Dr Symington, Prof. Thane, and the Honorary Secretary *ex officio*.

Dr JOHNSON SYMINGTON read a paper on *The Relations of the Peritoneum to the Descending Colon in the Human Subject*, which will be found *in extenso* in the body of the *Journal of Anatomy and Physiology*, p. 530.

The PRESIDENT remarked on the importance of having a clear notion of the meaning of the term "mesentery." Mere laxity of the peritoneum would not constitute a mesentery unless the two layers were closely apposed to each other.

Professor ANDERSON said it was rare to meet with a true mesentery in the performance of colotomy. The relation of the peritoneum to the descending colon varies with the amount of distension of the gut. Thus in the dissecting-room it is not uncommon to meet with the two layers almost in contact when the gut is collapsed, but when a moderate amount of distension is produced by injection or inflation, the normal arrangement is at once assumed.

Professor THANE expressed his concurrence with the views enunciated by Dr Symington and Prof. Anderson as to the comparative rarity of a true mesentery.

Dr H. D. ROLLESTON gave a *resumé* of a paper *On some Points in the Anatomy of the Supra-Renal Capsules*, illustrating the same by preparations and microscopic sections. The paper will be found *in extenso* in the body of the *Journal of Anatomy and Physiology*, p. 548.

Mr R. W. MICHELL, M.A., communicated the following *Note on the Topography of the Rectum*:—

The English text-books of human anatomy agree in describing the course of the rectum and its relations to the peritoneum in the same, or nearly the same, way.

They either tell us that the gut passes from left to right to reach the mid-line of the sacrum, and then follows the curve of that bone, or that the gut passes slightly across the mid-line to the right side, then turns on itself and reaches the mid-line again in front of the body of the 3rd sacral vertebra, from which point it follows the curve of the sacrum.

They also tell us that the peritoneum forms a meso-rectum which is complete, short, and ties the rectum firmly in one or other of the situations above described.

These two statements seem to be more dogmatic than is warranted by the evidence.

If a large number of rectums be examined, a considerable variety in the position of the gut will be noticed.

Those rectums which are distended, especially those which are distended before death, will, for the most part, be found placed so much to the right of the mid-line of the sacrum that they are in front of the right internal iliac artery.

Distension seemingly increases the bend of the first part of the rectum.

Those rectums which are small and contracted for the most part do not pass so far across the mid-line to the right as those do which are distended, but if in these cases the gut be injected with hot-water through the descending colon to soften the surrounding fat, it will be observed that the rectum dilates, and, while it dilates, changes its position for one more on the right side. The bend of the first part is greatly increased, and the rectum swings or slides across the front of the sacrum. The movement appears to be either a swing or a slide.

In the first case the gut moves like a gate on its post, in the second it does not.

When some of the rectums were examined, they were found to be without the definite meso-rectum of the books; the peritoneum did not cover the back of the gut.

These cases were of those in which *ante-mortem* distension was a feature. This seemingly pointed to an inverse relationship between the presence of distension and the presence of a meso-rectum.

To try whether this were so or not, the pelvis was filled with water hot enough to feel warm to the hand, and the fat was thus melted after a time.

The rectums experimented with were of those which were not distended at all, or very slightly so. Hot-water was injected, and in very many cases the gut slid under the peritoneum over to the right side, and became an anterior relation to the right internal iliac artery.

About the time that these observations were made, Prof. Macalister made a transverse section of a frozen body in which the rectum and bladder were fully distended at the time of death with fæces and urine respectively. In this specimen the rectum extended to the right of the mid-line, and the right internal iliac artery had a posterior relation to it.

Further evidence in favour of the view that a distended rectum crosses farther to the right than does any undistended one is seen in the following numbers deduced from my observation. Number of bodies examined, 116; number of times the gut was in front of the right internal iliac artery, 75.

Some of these were noted because the dextral extension of the gut was a marked feature, but many were taken at random. No record has been kept of the numbers of each class, so the percentage is probably higher than it would have been had this feature been sought in all bodies. The results of later experience point to the proportion

being larger than 75 out of 116, and to the sliding of the rectum as distinguished from its swinging being its most frequent manner of passing across to the right.

Mr C. DUDLEY COOPER (introduced by Prof. Thane) showed the *Skull of an Aboriginal Australian*, which had been found as part of a complete skeleton at Williamstown, Victoria.

The capacity of the skull was 1500 c.c., which was greater than any recorded by Prof. Flower¹ by 40 c.c., and far above his average of 1298 c.c. for 32 skulls examined. The average given by MM. de Quatrefages and Hamy² is 1269 c.c., and 1230 c.c. by Sir William Turner,³ based on an examination of 34 skulls. The latter, however, mentions the skull of a male from Port Curtis, Queensland, whose cranial capacity was 1514 c.c.

The teeth were in a very good state of preservation, and, except for the right upper central incisor, all were present.

The crowns of the teeth of the molar and premolar series were very much ground down, as were also, but to a lesser degree, the canines and incisors.

The degree of usure of the teeth corresponded to No. 3 of Broca's⁴ scale.

When the lower jaw was articulated with the upper, it was seen that in accordance with the observation of Sir William Turner,⁵ the two sets of incisors were in contact by their free cutting edges.

That the crowns of the corresponding teeth of the upper and lower jaws in the majority of Australian skulls were not in the same vertical plane, was well borne out by the specimen shown. In this skull the crown of the lower wisdom-tooth projected somewhat behind the upper wisdom. The second molars were in almost a vertical plane, but the remaining molar and premolar teeth of the lower jaw were situated slightly in front of the corresponding upper teeth.

The alveolar or gnathic index was 103·8 mm., slightly above Prof. Flower's mean of 103·6 for 51 specimens examined. The skull therefore belonged to the prognathous group.

The mean gnathic index in Sir William Turner's specimens was 100·3 mm., making the average mesognathic. Two specimens, however, had the high gnathic indices of 108.

The width of the upper dentary arcade, between the first molar teeth, was 67 mm., the maximum of Sir William Turner's measurements of 18 skulls being 66 mm. The width taken between the second molars was 72 mm., being slightly below the 73 mm. maximum of Turner.⁶ Between the wisdom-teeth the width of the arcade was 70 mm., Turner's maximum measurement in the same situation being 75 mm. The width of the lower dentary arcade, taken between the first molar teeth, was 61 mm., Turner's maximum being 63 mm.

¹ *Catalogue of Museum, Royal College of Surgeons, Part I., Man.*

² *Crania Ethnica.*

³ *Voyage of H.M.S. Challenger—Report on the Human Crania.*

⁴ *Instructions craniologiques et craniométriques.*

⁵ *Jour. of Anat. and Phys., July 1891.*

⁶ *Ibid.*

Opposite the second molars the width was 66 mm., as compared with 69 of Turner's, and between the two lower wisdoms the width was 70 mm., Turner's maximum of 11 skulls measured exceeding it by 2 mm.

The measurements showed that the upper jaw exceeded the lower in width between the first molars by 6 mm., Turner's average measurement in the same situation being 5 mm.

Between the second molars, the excess of the upper over the lower jaw was also 6 mm., 4 mm. being Turner's average excess.

The antero-posterior measurement of the crowns of the molar and premolar teeth was, in the upper jaw on the right side, 51 mm.; on the left, 49; giving an average of 50 mm., being very close upon Turner's maximum of 51 mm.

In the lower jaw the measurements were on the right side 53 mm., on the left side 53 mm., Turner's maximum being 56 mm. The excess of the lower antero-posterior diameter over the upper was 3 mm., exactly the same as Turner's average excess, both for Australians and Europeans.

The antero-posterior measurement of the true molar series gave in the upper jaw on the right side 34 mm., on the left 33 mm., being an average of 33.5, somewhat below Turner's maximum of 36 mm.

In the lower jaw on the right side the antero-posterior diameter was 38 mm., and on the left side 38 mm., as compared with 40 mm. maximum of Sir William Turner.

The excess of lower over upper jaw in the antero-posterior diameter of crowns of the true molar teeth was 4.5 mm., Turner's average excess being 2.8, and his maximum excess being 5 mm.

Other measurements (all of which were taken with the help of Professor Thane) were :—

Dental index of Flower,	.	.	47.1 mm.
Symphysial angle,	.	.	100°
Mandibular angle,	.	.	120°

Mr A. EICHHOLZ, B.A., communicated a paper on a *Racial Variation in the Length of the Palate Process of the Maxilla*. The paper is printed *in extenso* at p. 538 of the *Journal of Anatomy and Physiology*.

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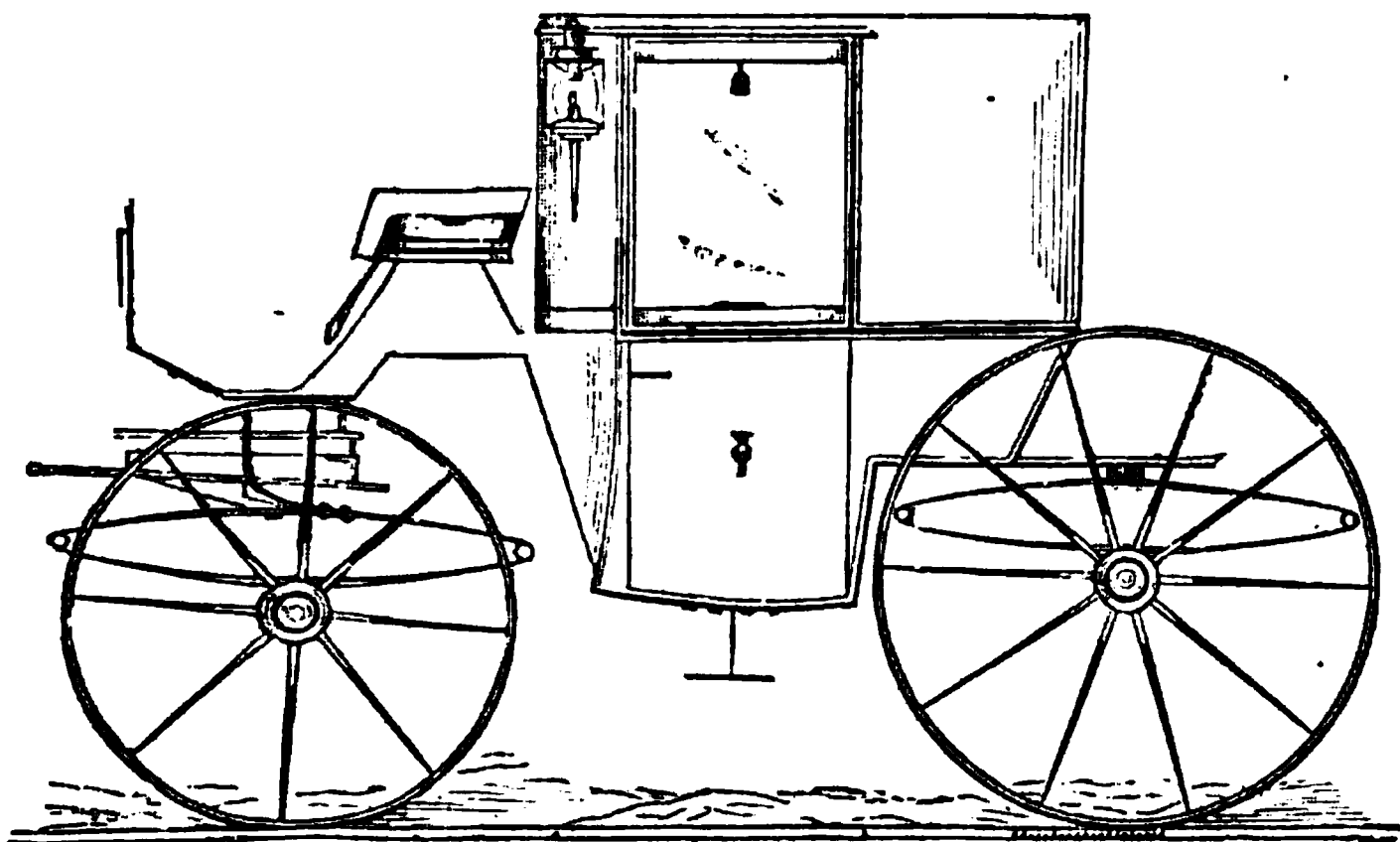
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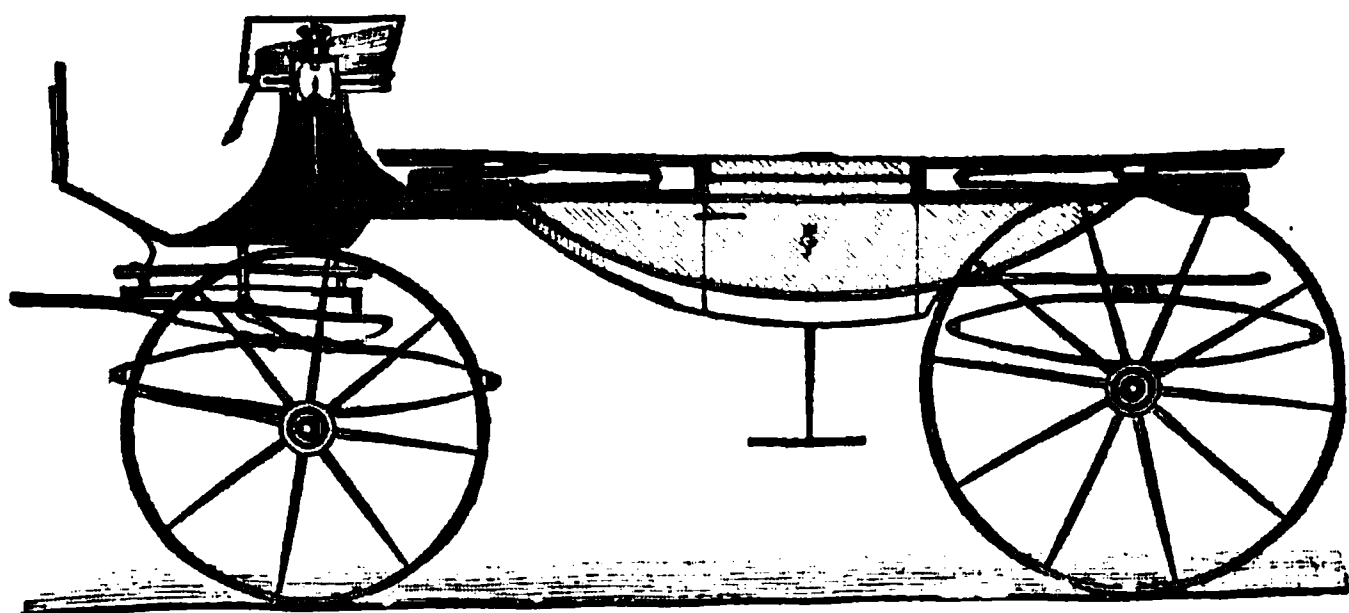
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